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Preface

This volume continues publications in marine science with special reference to the Gulf of Mexico. Papers are edited by the staff of the Institute of Marine Science, and there is no established editor. The undersigned acts largely in an "*ex officio*" capacity.

Occasionally referees from other institutions are utilized when required. Referees take full responsibility for their criticisms and complete signed statements will be furnished all authors. By thus procedure the ofttimes superficial and uncritical remarks of anonymous referees are avoided. Even at its best the anonymous referee system carries the stigma of "*sub rosa*" action which seems to be contrary to straightforward democratic principles. In any case, it indicates a lack of desire to shoulder responsibilities and the system appears to have more harmful potentialities than good ones.

This journal is operated on the assumption that authors in general know a great deal more about their papers and how they should be presented than editorial staffs do. Therefore, wishes of the authors are usually followed in publication even though they might be questioned by the editorial staff. There is no subscription list to this journal although individual volumes may be purchased. For that reason no provision is made for free reprints. Manuscripts should be submitted to the undersigned.

Gordon Gunter,
Acting Director,
Port Aransas, Texas.

The Littoral Marine Annelids of the Gulf of Mexico[1]

By

OLGA HARTMAN

Allan Hancock Foundation, University of Southern California

The aim of the present study is mainly to publish the presence of a rich and flourishing annelid fauna in the Gulf of Mexico. Keys and illustrations together with the bibliographic citations may permit a fairly complete and accurate identification of the annelids to be encountered in littoral zones. The collections upon which this study was based come largely from intertidal or shallow seas; only a few are from deeper waters. This investigation has disclosed the existence of a vast, diversified, possibly highly endemic fauna in this area. The few deeper water species that have been reported show affinities with those known also from the West Indies and the tropical Atlantic Ocean.

One hundred fifty-eight species in 110 genera and 36 families of marine annelids are recorded, most of them for the first time from the Gulf of Mexico. There are 15 new species or subspecies, one new name and one new genus. These are listed by family.

LIST OF SPECIES

POLYNOIDAE

Lepidametria commensalis Webster
Lepidonotus sublevis Verrill
Lepidonotus variabilis Webster
Halosydna leucohyba Schmarda
Harmothoë aculeata Andrews
Harmothoë trimaculata (Treadwell)

POLYODONTIDAE

Eupanthalis tubifex (Ehlers)
Polyodontes lupina (Stimpson)

SIGALIONIDAE

Sthenelais articulata Kinberg

AMPHINOMIDAE

Amphinome rostrata (Pallas)
Chloeia viridis Schmarda
Eurythoë complanata (Pallas)
Hermodice carunculata (Pallas)
Hipponoë multibranchiata (Treadwell)
Pareurythoë americana, new species

PHYLLODOCIDAE

Anaitides erythrophyllus (Schmarda)
Eteone heteropoda n. sp.
Eteone alba Webster
Eulalia myriacyclum (Schmarda)
Eumida sanguinea (Oersted)
Nereiphylla fragilis (Webster)
Nereiphylla, near *paretti* Blainville

HESIONIDAE

Hesione picta Müller
Podarke, near *guanica* Hoagland

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[1]Contribution no. 75 from the Allan Hancock Foundation of the University of Southern California.

PILARGIIDAE

Ancistrosyllis bassi Hartman
Loandalia americana Hartman

SYLLIDAE

Autolytus brevicirrata Winternitz
Exogone dispar (Webster)
Ehlersia, sp.
Haplosyllis spongicola (Grube)
Odontosyllis enopla Verrill
Synsyllis longigularis Verrill
Trypanosyllis vittigera Ehlers
Typosyllis corallicoides Augener

NEREIDAE

Ceratonereis irritabilis (Webster)
Ceratonereis mirabilis Kinberg
Ceratonereis tridentata (Webster)
Laeonereis culveri (Webster)
Lycastopsis tecolutlensis Rioja
Neanthes succinea (Frey and Leuckart)
Nereis largoensis Treadwell
Nereis oligohalina (Rioja)
Nereis pelagica occidentalis Hartman
Nereis riisei Grube
Perinereis anderssoni Kinberg
Perinereis floridana (Ehlers)
Platynereis dumerilii (Audouin and M. Edwards)

NEPHTYIDAE

Nephtys bucera Ehlers
Nephtys picta Ehlers

GLYCERIDAE

Glycera americana Leidy
Glycera dibranchiata Ehlers

ONUPHIDAE

Diopatra cuprea (Bosc)
Hyalinoecia tubicola (Müller)
Onuphis eremita oculata, new subspecies
Onuphis magna (Andrews)

EUNICIDAE

Eunice filamentosa Grube
Eunice floridana (Pourtalés)
Eunice mutilata Webster
Eunice rubra Grube
Eunice schemacephala Schmarda
Eunice (Nicidion) kinbergi Webster
Lysidice ninetta Audouin and M. Edwards
Marphysa regalis Verrill
Marphysa sanguinea (Montagu)
Palola siciliensis (Grube)

LUMBRINERIDAE

Lumbrineris alata, new species
Lumbrineris bassi Hartman
Lumbrineris inflata (Moore)
Lumbrineris parvapedata (Treadwell)
Ninoë nigripes gracilis, new subspecies

ARABELLIDAE

Arabella iricolor (Montagu)
Drilonereis magna (Webster and Benedict)
Drilonereis cylindrica, new species

LYSARETIDAE

Lysarete brasiliensis Kinberg

DORVILLEIDAE

Dorvillea rubra (Grube)
Dorvillea rudolphii (delle Chiaje)
Dorvillea sociabilis (Webster)

ORBINIIDAE

Haploscoloplos foliosus, new species
Haploscoloplos fragilis (Verrill)
Haploscoloplos robustus (Verrill)
Naineris bicornis, new species
Naineris laevigata (Grube)
Naineris setosa (Verrill)
Phylo ornatus (Verrill)
Scoloplos (Leodamas) rubra (Webster)

SPIONIDAE

Dispio uncinata, new genus and species
Nerine agilis Verrill
Polydora armata Langerhans
Polydora caulleryi Mesnil
Polydora hamata Webster
Polydora ligni Webster
Polydora socialis (Schmarda)
Polydora websteri Hartman
Prionospio heterobranchia texana, new subspecies
Prionospio treadwelli, new name
Prionospio ?cirrifera Wirén
Spiophanes bombyx (Claparède)

MAGELONIDAE

Magelona, near *californica* Hartman

CHAETOPTERIDAE

Chaetopterus variopedatus (Renier)
Spiochaetopterus oculatus Webster

CIRRATULIDAE

Cirratulus hedgpethi, new species
Cirriformia filigera (delle Chiaje)
Dodecaceria diceria, new species
Dodecaceria near *concharum* Oersted

ARENICOLIDAE

Arenicola cristata Stimpson

OPHELIIDAE

Armandia agilis (Andrews)
Polyophthalmus pictus (Dujardin)

FLABELLIGERIDAE

Semiodera roberti, new species
Stylarioides inflata (Treadwell)

CAPITELLIDAE

Capitella capitata (Fabricius)
?Capitellides teres Treadwell
Dasybranchus lumbricoides Grube
Dasybranchus lunulatus Ehlers
Heteromastus filiformis (Claparède)
Notomastus hemipodus Hartman
Notomastus latericeus Sars
Mediomastus californiensis Hartman

MALDANIDAE

Axiothella mucosa (Andrews)
Branchioasychis americana Hartman
Clymenella torquata calida, new subspecies
?Macroclymene elongata (Webster)
Maldane sarsi Malmgren

OWENIIDAE

Owenia fusiformis delle Chiaje

PECTINARIIDAE

Cistenides gouldii Verrill

SABELLARIIDAE

Sabellaria floridensis Hartman
Sabellaria vulgaris beaufortensis Hartman

AMPHARETIDAE

Amphicteis gunneri floridus, new subsp.
Melinna maculata Webster

TEREBELLIDAE

Enoplobranchus sanguineus Verrill
Loimia medusa (Savigny)
Loimia viridis Moore
Pista cristata (Müller)
Pista palmata (Verrill)
Terebella rubra (Verrill)
Terebellides stroemi Sars
Thelepus setosus (Quatrefages)

SABELLIDAE

Branchiomma bairdi (McIntosh)
Branchiomma nigromaculata (Baird)
Chone duneri Malmgren
Fabricia, sp.
Hypsicomus elegans (Webster)
Megalomma bioculatum (Ehlers)
Megalomma lobiferum (Ehlers)
Sabella melanostigma Schmarda
Sabella microphthalma Verrill
Sabellastarte magnifica (Shaw)

SERPULIDAE

Eupomatus dianthus (Verrill)
Eupomatus protulicola (Benedict)
Eupomatus sanctae-crucis (Mörch)
Mercierellopsis prietoi Rioja
Pomatoceros minutus Rioja
Pomatoceros (Pomatoleios) caerulescens Augener
Protula tubularia (Montagu)
Salmacina dysteri (Huxley)
Vermiliopsis annulata (Schmarda)
Vermiliopsis bermudensis (Bush)
Dexiospira corrugata (Montagu)
Dexiospira spirillum (Linnaeus)

Twenty-eight additional species are listed from Long Bush Key, Dry Tortugas, Florida by Monro (1933, pp. 244–268) bringing the total number of species to 182, of genera to 118 and of families to 37. These 28 species with family names are:

APHRODITIDAE: *Aphrodita obtecta* Ehlers.

SIGALIONIDAE: *Sthenelais boa* (Johnston) and *Sigalion mathildae* Audouin and M. Edwards.

CHRYSOPETALIDAE: *Chrysopetalum debile* Grube.

SYLLIDAE (most of the 8 species here named are redescribed by Monro): *Syllis prolifera* Krohn, *S. tigrinoides* Augener, *S. variegata* Grube, *S. corallicola* Verrill, *S. fuscosuturata* Augener, *S. tortugaensis* Augener, *S. cincinnata* Verrill and *Opisthosyllis nuchalis* Verrill.

NEREIDAE: *Ceratonereis versipedata* (Ehlers).

EUNICIDAE: *Eunice macrobranchia* Schmarda, *E. cariboa* Grube and *Parmarphysa longula* Ehlers.

LUMBRINERIDAE: *Lumbrineris heteropoda* Marenzeller, *L. floridana* Ehlers and variety *polygnatha* Monro.

ARABELLIDAE: *Arabella novecrinita* Crossland.

CIRRATULIDAE: *Cirratulus punctatus* Grube and *Cirriformia tortugaensis* (Augener).

CTENODRILIDAE: *Ctenodrilus serratus* (O. Schmidt).

OPHELIIDAE: *Armandia maculata* (Webster).

TEREBELLIDAE: *Lanicides bilobata antillensis* Augener.

SERPULIDAE: *Crucigera websteri* Benedict, *Pomatostegus stellatus* (Abildgaard), and *Spirobranchus giganteus* (Pallas).

Extensive shorelines of the Gulf of Mexico at its eastern, northern and western fringes are long, smooth sandy beaches (plates 1, 2) occasionally interrupted by inlets, salt marshes or other low-lying topographic features. Early travelers and explorers were awed and considerably inconvenienced. Thus Father Charlevoix (1766) in his geographic description of the Gulf of Mexico, described Biloxi as extremely flat, with its only anchorage full of "worms" which damage all the ships. The coast along Louisiana, near New Orleans was also sand.

Most prominent and influential is the delta system of the Mississippi River. This is constantly replenishing the detritus and nutrient salts needed to provide a flourishing and continuous growth. Its influences in supporting a distinct fauna, in so far as it concerns the annelids, is clearly manifest in the large numbers of unique species it supports. This realm of influence in maintaining a Delta Fauna need not be confined to the immediate environs of the delta; it may extend itself well beyond the horizontal and vertical fringes that mark the freshening effects of the river.

Four major categories are recognizable in the annelid fauna of the Gulf of Mexico. A dominant, possibly endemic group are those species of the Delta Fauna; this includes the 14 new species or subspecies described below, also 9 (or more) others *(Nereis largoensis, Lumbrineris bassi, Lumbrineris parvapedata, Notomastus hemipodus, ? Capitellides teres,* a species of *Fabricia, Laeonereis culveri, Branchioasychis americana, Nereis occidentalis pelagica).*

Another large and conspicuous group are the species with West Indian affinities. This includes the EUNICEA and AMPHINOMIDAE, as well as some sabellids, serpulids and some others. They are found in the Gulf especially in Florida, eastern Mexico and in the deeper waters of the Gulf. A third and less easily identifiable group comprises the species that occur also along the eastern shores of the United States, northward to New England. A fourth group consists of species which might be considered circummundane, in warm tropical seas; such are the species *Ceratonereis mirabilis* Kinberg, *Arabella iricolor* (Montagu), *Haplosyllis spongicola* (Grube) and others. If the range extends more considerably they may be known as cosmopolitan species, such as *Dexiospira spirillum* (Linnaeus). Another smaller group comprises the species with a very wide distribution in deeper waters, such as *Maldane sarsi* and *Pista cristata* (Müller). Brackish or euryhaline species comprise another category; to it belong *Neanthes succinea* (Frey and Leuckart) and *Mercierellopsis prietoi* Rioja.

Especially noteworthy is the occurrence of several rare or obscure groups in the Gulf of Mexico, such as the species in the family PILARGIIDAE,, MAGELONIDAE, the genus *Dispio* of the SPIONIDAE, and the several species of ORBINIIDAE.

The physical and known oceanographic features of much of the northern and western ends of the Gulf of Mexico have been detailed or summarized in articles cited by Geyer, 1950.

The collector, whether he be an inveterate or novice at turning the shovel or sifting sands in low intertidal zones, is almost certain to recover new and little known groups

PLATE 1

Top. Bald Point, Ochlochonee River, northwestern Florida, at low tide; x marks place where *Axiothella* tubes are abundant. (L. M. Henry.)

Middle. Alligator Point, Franklin Co., Florida, typically strewn with seaweed. 1950. (L. M. Henry.)

Bottom. Beach on Ship Island offshore from Biloxi, Mississippi, April, 1950. (A. E. Hartman.)

among the marine worms. Most rewarding are those areas within or adjacent to low drainage channels, or in areas where organic detritus is brought in by brackish or freshwater streams, or those regions somewhat overgrown with a light algal cover (pl. 1, middle). Very soft ooze or mud substrata are apt to yield richly with rare and little known species but the difficulties of approach usually limit the degree of probing and sorting. In such places the use of screens or nets with varying meshes can result in materials that are noteworthy and interesting. The experienced collector will select those areas which are the feeding grounds of flocks of birds or schools of fishes. Other areas equally compensating are the associations to be found in drifting objects such as logs, floating buoys, bottoms of boats or piers that are submerged, or low piles buried in sand or mud. Aggregated clumps of oysters, ascidians, sponges or other biotic materials are sometimes teeming with myriads of smaller forms including many species of worms. Also the discarded tests of echinoids, snail shells, arthropod carapaces, beachworn oyster shells or porous calcareous clumps may contain the habitats of numerous species.

The beauty of many of the marine annelids in life can be most fully appreciated when individuals are cleared of debris and allowed to swim or crawl in a dish of clean sea water. Specimens having much external debris and mucus can usually be cleaned by allowing them to creep through layers of clean sand in sea water. The striking iridescence or opalescence of some of the EUNICEA or the rhythmic symmetry of color patterns such as occur in the feather-duster, *Branchiomma nigromaculata* (Baird), the sharply contrasting colors and gleaming white bristles of the fireworms (AMPHINOMIDAE) together with their remarkable progression in swimming, are objects of striking interest.

The presence of annelids associated with other organisms, sometimes called commensals, mess-mates or other implied alliances, is of interest and often surprising to the field collector. Thus, the tubes of many of the larger terebellids are apt to harbor scale-bearing worms especially of the genera *Lepidametria* and *Halosydna;* tubes of *Chaetopterus* may have not only polynoids but pinnotherid crabs. The under surface of the sea pansy usually conceals a small scale-worm, *Lepidonotus sublevis* Verrill, and many sponges, bryozoans and algae give support to syllids and opheliids; *Podarke* is apt to be associated with echinoids and *Hipponoë* may be expected with goose-neck barnacles on drifting wood. Many of these annelids have color patterns that simulate those of the host and are thus apt to be overlooked.

The Gulf of Mexico together with the Caribbean Sea has sometimes been called the American Mediterranean. This appellation seems unfortunate to me since it implies a homologous condition, biologically and environmentally that does not exist. The annelid fauna is certainly different. The few annelid species, such as *Platynereis dumerilii* (Audouin and M. Edwards), *Marphysa sanguinea* (Montagu), *Chaetopterus variopedatus* (Renier) and others that might be named, are common to many other areas and may be regarded cosmopolitan. Far more numerous are the large number of species that are present in the Gulf of Mexico and absent from the Mediterranean Sea. The annelids of the Gulf of Mexico have their nearest affinities with those of adjacent regions of the American coasts, notably south to Brazil and north to New England, and in the eastern Pacific north to southern California.

Most important references to consult are those of Ehlers (1887) which has colored plates of some species, Webster (1879 and 1882) and Andrews (several). Fauvel's

PLATE 2

Top. Grand Isle, Louisiana, showing driftwood on beach, October, 1950. (A. E. Hartman.)

Middle. Channel from Ocean Springs, with Deer Island, Mississippi in distance, April, 1949. (A. E. Hartman.)

Bottom. Vicinity of Port Aransas, Texas with Institute of Marine Science, The University of Texas in background, October, 1950. (A. E. Hartman.)

Monograph for France (1923 and 1927) is valuable for providing illustrated keys to many genera, and Hartman (1944 and 1945) includes species occurring in adjacent areas.

I am indebted to the Administration of the Allan Hancock Foundation of the University of Southern California for material aid in completing this report. To the American Museum of Natural History, New York, I owe thanks for the examination of valuable type materials. The U.S. National Museum loaned materials at various times. Many individuals have aided in bringing the collections together. The estate of the late John Bass, Bass Biological Laboratory at Englewood, Florida supported my stay in 1938. To the following persons I am indebted for specimens: to M. Woodbridge Williams from near Biloxi, Mississippi, to Dr. Ellinor H. Behre and J. H. Roberts from Grand Isle, Louisiana, to Laura M. Henry, Donald Carpenter and Dr. Harold J. Humm from northwestern Florida and to Albert E. Hartman from Texas, Mississippi and Louisiana. To Dr. Willis G. Hewatt, Texas Christian University, I am indebted for material from Puerto Rico which was valuable for comparison, and to Joel W. Hedgpeth for having provided large lots from south Texas. The scientific staff members of the cruises of the M/V OREGON, investigating shrimp populations in the Gulf of Mexico, provided some interesting dredged forms. All of the plates except 1–3, 6, 13, 14, were prepared by Anker Petersen, staff artist of the Allan Hancock Foundation of the University of Southern California. Types of all species and collections are deposited in the Allan Hancock Foundation of the University of Southern California.

The Scale-Bearing Annelids

Annelids having scales or elytra are represented by 3 families. The elytra are paired, flattened, notopodial processes that replace the dorsal cirri on some segments. They may be superficially covered by a matted layer of felt (modified notosetae) as in the sea mouse (family APHRODITIDAE). In some species the scales completely cover the dorsal surface of the body; in others a middorsal stripe or a posterior portion is uncovered. The number and distribution of these parts is of major diagnostic significance.

Key to Families

1. Body short, oval, scales concealed and covered with a thick layer of mat or felt ..... APHRODITIDAE (see Ehlers, 1887, pl. 6)
1. Body short to long, the scales not covered with felt 2
2. Scales present on all segments after the middle region of the body ..... SIGALIONIDAE
2. Scales present on alternate segments or lacking from the posterior part of the body 3
3. Posterior segments with scales on every third segment or these absent; prostomial eyes sessile, none on stalk; errantiate ..... POLYNOIDAE
3. Posterior scales replaced by cirri on every third segment; anterior prostomial eyes sessile or on long stalk; tubicolous ..... POLYODONTIDAE

Family POLYNOIDAE

The body is short, of few or limited number of segments, to long with many segments *(Lepidametria)*. The elytral pairs number 12 to 18 or many. Six species are recorded.

PLATE 3

Top. Serpulid tube mass taken from bottom of boat in drydock at Aransas Pass, Texas. (A. E. Hartman.) (The electric wall socket in the rear allows for approximate sizes.)

Bottom. Empty tubes of *Diopatra cuprea* (Bosc) on Padre Island, eastern Texas, washed in after storm, October, 1950. (A. E. Hartman.)

Key to Species

1. Elytra number 12 pairs ..... *Lepidonotus* 2
1. Elytra number 15 pairs ..... *Harmothoë* 3
1. Elytra number 18 pairs ..... *Halosydna leucohyba*
1. Elytra number over 25 pairs ..... *Lepidametria commensalis*
2. Elytra with long marginal fringe; neurosetae distally bifid ..... *Lepidonotus variabilis*
2. Elytra with short marginal fringe; body trim; neurosetae distally entire ..... *Lepidonotus sublevis*
3. Elytra with long, heavy fringe at outer margins; dorsal cirri heavily pilose ..... *Harmothoë aculeata*
3. Elytra without heavy fringe, their dorsal surface with 3 dark spots of pigment, 2 near elytral scar and one farther back; dorsal cirri hirsute ..... *Harmothoë trimaculata*

Lepidametria commensalis Webster, 1879

Lepidametria commensalis Webster, 1879, pp. 210–213, pl. 3, figs. 23–31; Hartman, 1945, p. 10; Behre, 1950, p. 11.

Lepidasthenia lactea Treadwell, 1939, pp. 3–5, figs. 13–15.

This comes from Englewood, Florida in shallow water from bottom of shell aggregates and debris, from tubes of tubicolous annelids especially *Thelepus setosus* (Quatrefages) and other terebellid worms.

The body is 50 to 100 mm. long, depressed, dorsally covered with 35 or more pairs of scales that do not cover the body entirely. Elytra are somewhat translucent and usually have small blotches of gray to black pigment. Dorsal and peristomial cirri are dark at the base and at the subdistal thickening; elsewhere they are white.

In the Gulf of Mexico this has been previously reported from Grand Isle, Louisiana by Behre (1950) and from Galveston, Texas, as *Lepidathenia lactea* Treadwell (1939). It is more widely known from Virginia to Connecticut and North Carolina (Hartman, 1945).

Lepidonotus sublevis Verrill, 1873

Lepidonotus pallidus Treadwell, 1939, p. 3, figs. 10–12.

Lepidonotus sublevis Hartman, 1942, pp. 22–23, figs. 8–12; Hedgpeth, 1950, p. 75; Behre, 1950, p. 11.

?Lepidonotus squamatus Warren, 1942, p. 45; Behre, 1950, p. 11.

Numerous individuals come from Englewood, Florida in grooves of whelk shells occupied by hermit crabs; others are trawled from shallow water on bottom with sea urchins and ascidians. In Texas it occurs on the under surface of the sea pansy, *Renilla mülleri* Kölliker (Hedgpeth, 1950, p. 75). A common habitat is shelly grounds or any niches where crevices abound.

The 12 pairs of elytra are more or less firmly attached and have only microtubercles dispersed over the upper surface. Notosetae are very fine, hairlike and numerous. Neurosetae are much coarser, distally entire and none is distinctly heavier although there is a gradual thickening of the shaft in the uppermost part of the fascicle. The neuropodial flange is somewhat ruffled about its upper margin where it surrounds

the base of neurosetae. Nephridial papillae are inconspicuous and tend to be turned upward in segmental grooves.

In some specimens from Texas and Lemon Bay, Florida the lateral elytral fringe is longer than usual and there is a prolonged tuft at the outer, posterior edge, somewhat as in *L. variabilis* (below). The prostomial antennae are more prolonged distally so as to extend out beyond the palpal bases and other tentacular processes are likewise longer than usual. In other respects, however, especially in having entire neurosetae, the specimens agree with *L. sublevis* Verrill.

Lepidonotus squamatus Warren (1942) and Behre (1950) from Grand Isle, Louisiana is questionably referred to this species since the records are possibly to this, rather than to the cold-water *L. squamatus* (Linnaeus).

Lepidonotus sublevis Verrill occurs along the eastern shores of the United States, from New England to southern Florida and in the Gulf of Mexico.

Lepidonotus variabilis Webster, 1879

Lepidonotus variabilis Webster, 1879, pp. 205–208, pl. 1, figs. 6–11, pl. 2, figs. 12–14; Warren, 1942, p. 45; Hartman, 1945, p. 10; Behre, 1950, p. 11.

Many individuals come from near Englewood, Florida, in mixed sand both intertidal and trawled from shallow water in ascidian masses; two others are from Apalachicola Bay, Florida (coll. L. M. Henry). The species occurs in crevices of sponges, oysters, etc.

The 12 pairs of elytra are fringed at their outer margins and have a prolonged tuft of hairs usually at the inner posterior edge; their upper surface is mottled gray or brown. Elytra are easily detached on preserved specimens. Neurosetae are distally bidentate. The ventrally located nephridial papillae are more conspicuous than are those in *L. sublevis* (above) and directed ventrally. Compared with the trim overall appearance of *L. sublevis,* this species looks untidy. The color pattern is variable, hence the specific name, but in general the color is grayish brown usually with a white spot over the elytral scar, or this spot is dark.

L. variabilis is known along the eastern United States south to the West Indies.

Halosydna leucohyba Schmarda, 1861

Halosydna leucohyba Webster, 1884, pp. 309–310, pl. 7, figs. 16–18, pl. 8, figs. 19, 20; Rioja, 1946, p. 193.

This is recorded from Veracruz and Tampico, Mexico, from between shells and calcareous algae by Rioja (1946).

The 18 pairs of elytra are firmly attached and nearly or entirely cover the body. Notosetae are present in a reduced fascicle. Neuropodia are much larger than notopodia and have a thick fascicle of distally bifid hooks. The general shape of the body is rectilinear, depressed and trim.

This is typically a West Indian intertidal species, known also from Bermuda. Its presence in the Gulf of Mexico seems to be restricted.

Harmothoë aculeata Andrews, 1891

Harmothoë aculeata Andrews, 1891, pp. 278–279, pl. 12, figs. 1–5; Hartman, 1945, p. 10.

Two individuals come from southwestern Florida from crevices and in growths on piles exposed at low tide.

The dorsal surface is completely covered by the 15 pairs of heavily fringed elytra. The body is considerably depressed and tapers to rounded ends. The prostomial antennae, peristomial and dorsal cirri are heavily pilose. Neurosetae are distally bidentate.

This species is known elsewhere at North Carolina.

Harmothoë trimaculata (Treadwell), 1924

Evarnella trimaculata Treadwell, 1924, pp. 6–7, figs. 1–3.

Harmothoë trimaculata Hartman, 1938, p. 118, figs. 38, 39; Rioja, 1946, p. 193.

This is reported from Tecolutla, eastern Mexico among mollusk shells by Rioja (1946).

The species is separable from *Harmothoë aculeata* (above) for having few (about 12) heavy notosetae and slenderer neurosetae in which the tip is broadly bidentate with the secondary tooth widely separated from the main fang.

The specific name may be replaceable by *Harmothoë variegata* Treadwell (1917) from southwestern Florida; the two seem hardly separable. As the latter the species is known also from the West Indies.

Family POLYODONTIDAE

The body is long, has many (100 or more) segments and elytral pairs. The mid-dorsum is broadly exposed. Parapodia have conspicuous spinning glands. The prostomium has 2 pairs of eyes of which the anterior pair is sessile or on long stalks. Individuals inhabit thick-walled tubes in which much silt and mud are incorporated. Two species are reported.

Key to Species

1. Anterior eyes stalked and large ..... *Polyodontes lupina*
1. Anterior eyes sessile, small ..... *Eupanthalis tubifex*

Polyodontes lupina (Stimpson), 1856

Acoetes lupina Stimpson, 1856, pp. 116–117; Andrews, 1891, p. 280.

Polyodontes lupina Hartman, 1945, p. 10; Behre, 1950, p. 11.

This is recorded from Grand Isle, Louisiana by Behre (1950).

Mature individuals come to be very large, attain a length of 75 cm. or more. The tube is thick, tough and fibrous; a smooth inner layer is covered with successive layers of fine dark mud held together with slender fibers secreted by the segmental spinning glands. The tube resembles an irregular cylinder of mud. The body is thick, depressed and strikingly patterned. The dorsal surface is opalescent to pale brown;

elytra are pale brown and have a narrow, chalky white border. The ventral surface of the body is light chocolate brown.

Polyodontes lupina is otherwise known only from North and South Carolina in muddy shoals.

Eupanthalis tubifex (Ehlers), 1887

Euarche tubifex Ehlers, 1887, pp. 54–56, pl. 12, figs. 1–7, pl. 13, fig. 1.

Ten tubes measuring 3 to 5 inches long, some with specimens, come from off south Texas, 27° 25′ N., 96° 13′ W., in 76 fms, November 27, 1950, taken by the M/V OREGON, station 157, with a 40′–4 balloon trawl. The bottom temperature was 60.5° F, surface 73° F.

The tube is neatly annulated at its anterior end, as first shown by Ehlers (pl. 13, fig. 1). The contained individuals are pale to white, measure to 77 mm. long and about 5 mm. wide. The original collections, coming from 28° 51′ N., 89° 1′ W. measured to 130 mm. long with the 9 mm. long everted proboscis and about 5 mm. wide. In all specimens examined the proboscis was completely extended. Abruptly after the thirtieth or thirty-fourth segment the body cavity is filled with sperm bundles or ova, according to the sex of the individual.

This species is known only off southern Florida and in the Gulf of Mexico.

Family SIGALIONIDAE

The body is long, covered with many pairs of scales that closely cover the posterior end; all posterior segments have paired elytra. The protomium has a conspicuous median antenna that is inserted on a basal article with lateral processes or ctenidia. Neurosetae are in part multiarticled. A single species is recorded but 2 others are reported from Dry Tortugas, Florida (see list, above).

Sthenelais articulata Kinberg, 1855

Eupholoe globosa Winternitz, 1936, p. 3, figs. 6–12.

Sthenelais leidyi Hartman, 1945, p. 10 (with synonymy); Behre, 1950, p. 12.

Sthenelais articulata Hartman, 1948, pp. 36–37, pl. 6, figs. 6–9.

Specimens come from root masses of narrow-leaved grasses and from trawled ascidian masses in Lemon Bay, southwestern Florida; others are from Grand Isle, Louisiana and from Aransas Bay at Lydia Ann Channel, Texas.

Individuals from the Gulf of Mexico are noticeably smaller than others from various parts of eastern United States, previously named *Sthenelais leidyi* Quatrefages, but in other respects I believe the specimens are identical.

Length approaches 50 mm. or less. The body is long, rectilinear; it is closely covered by many pairs of deeply imbricated scales that are pale to dark reddish brown or rust-colored. The ventral cirri of the second segment are much longer than are those on successive segments. Elytral processes are uniformly small, subconical, with a triangular, Y-shaped chitinized ridge. The fringe on the anterior side of the neurosetal margin is variously developed; in some there is a long fringe

(specimens from New England to North Carolina), in others it is short (Gulf of Mexico), and in others it is nearly or entirely absent (Brazil). The characteristic falcigerous setae are blunt, distally bifid; only a few neurosetae are multiarticled.

I am here referring *Eupholoe globosa* Winternitz (1936, p. 3) to this species since the two agree in the characters of the elytra and falcigerous neurosetae. *Sthenelais leidyi* Quatrefages (1865) and *Sthenelais picta* Verrill (1873) both from eastern United States, are probably the same.

Sthenelais articulata Kinberg thus occurs along eastern North and South America from New England south to Brazil and in the Gulf of Mexico from Florida at least to Louisiana.

Family AMPHINOMIDAE

The amphinomids or fire-worms are largely tropical, often brilliantly colored, sometimes conspicuously large, measuring to 15 or 20 inches long. They are to be encountered especially on floating timber or maritime buoys, in coralline habitats, or swimming in open seas in a pseudopelagic existence. They are essentially errantiate in habit and predaceous; a few are known to be parasitic *(Hipponoë)*. Some species, because of their size, color and serpentine manner of swimming, may account for tales of sea-serpents.

The common name, fire-worm alludes to the stinging sensation caused from handling specimens. The injury is mechanical, resulting from the penetration into the skin of numerous, fine, glass-like harpoon-shaped setae that are difficult to remove. Inflammation and considerable discomfort result but there is no permanent injury.

Seven species have been recovered from various parts of the Gulf of Mexico; others are doubtless to be found, especially from its warmer, deeper parts and in tropical currents. Identification is sometimes difficult unless microscopic details are examined. Immature specimens of large species can be confused with smaller ones. Retraction of diagnostic parts such as the prostomium and its associated parts has accounted for irregularities in descriptions, and the phenomenon of acquiring swimming setae at sexual maturity is further confusing. Although the color pattern in life is striking and diagnostic, this is apt to fade or disappear on fixation. A more satisfactory and definite character concerns the nature of the prostomial caruncle. This is visible at the posterior margin of the prostomium, unless it is withdrawn into the first few segments, as may sometimes be the case.

The family AMPHINOMIDAE includes the first species of annelids to be described from the Western Hemisphere. Peter Simon Pallas, having completed his medical training at Göttingen and Leyden at the age of 25 years, became interested in some tropical and West Indian collections that were deposited in museums of western Europe. Among them were *Amphinome rostrata* (Pallas), *Eurythoë complanata* (Pallas) and *Hermodice carunculata* (Pallas). The descriptions and illustrations made by Pallas (1766) still merit attention for their accuracy and interest.

Key to Species

1. Prostomial caruncle absent or nearly so (pl. 8, fig. 1); ventral side with paired series of heavy bifid spines (pl. 8, fig. 2) adapted for clinging ..... *Hipponoë multibranchiata*

1. With a well developed prostomial caruncle; ventral side without such spines 2
2. Body long, vermiform 3
2. Body short, oval, with conspicuous white setal tufts ..... *Chloeia viridis*
3. Prostomial caruncle conspicuous (pl. 4), clearly visible and more or less concealing the prostomium; lacking lateral lobes 4
3. Prostomial caruncle posteriorly prolonged and provided with lateral processes 6
4. Caruncle triangular to chordate in shape (pl. 4, fig. 1) ..... *Amphinome rostrata*
4. Caruncle long and narrow, straight or somewhat sinuous (pl. 6, fig. 1) 5
5. Caruncle laterally compressed and reduced to a narrow lobe at the middle of the fifst segment (pl. 6, fig. 1) ..... *Pareurythoë americana*
5. Caruncle with a ventral crenulate portion and a smooth dorsal extension (pl. 4, fig. 2) ..... *Eurythoë complanata*
6. Dorsal side of body conspicuously striated; caruncle with conspicuous paired processes (pl. 5, fig. 2) ..... *Pherecardia striata*
6. Dorsal side of body not striated; caruncle cushionlike (pl. 5, fig. 1) ..... *Hermodice carunculata*

Amphinome rostrata (Pallas), 1766

Plate 4, fig. 1

Aphrodita rostrata Pallas, 1766, p. 106, pl. 8, figs. 14–18.

Amphinome pallasii Ehlers, 1887, pp. 26–27, pl. 1, fig. 4 (colored).

Amphinome rostrata Augener, 1922, p. 39; Monro, 1933, p. 245; Hartman, 1945, p. 12; Behre, 1950, p. 11.

There are finds from Grand Isle, Louisiana, St. Joseph Island, Texas on *Sargassum*, Nov. 23, 1946 and off Port Aransas, Texas on *Sargassum* about the same time. The species has also been reported at Campeche Bank, Mexico by Augener (1922).

This attains a large size, 10 to 16 inches long, but most specimens are much smaller. The body is long, vermiform, with the anterior end broad and bluntly rounded. The prostomial caruncle (fig. 1) is heart-shaped and extends back to the middle of the first segment. Branchiae are large and bushy; they are present from the third segment and continued back to the end of the body.

In life the color of the body is drab green to ashy gray with orange red branchiae and cirri (see Ehlers, 1887, for colored plate); preserved the color is slaty blue and the cirri and branchiae are rust-colored; the ventrum is pale.

Brood care in which 20 juveniles, measuring to 10 mm. long are attached to an adult 90 mm. long, is described (Augener, 1922, p. 39).

This is a tropical, widely distributed species, associated especially with drifting logs or floating buoys and fronds of large algae; it is sometimes associated with the goose-neck barnacle. In the Gulf of Mexico it may be present through most of its extent.

Hermodice carunculata (Pallas), 1766

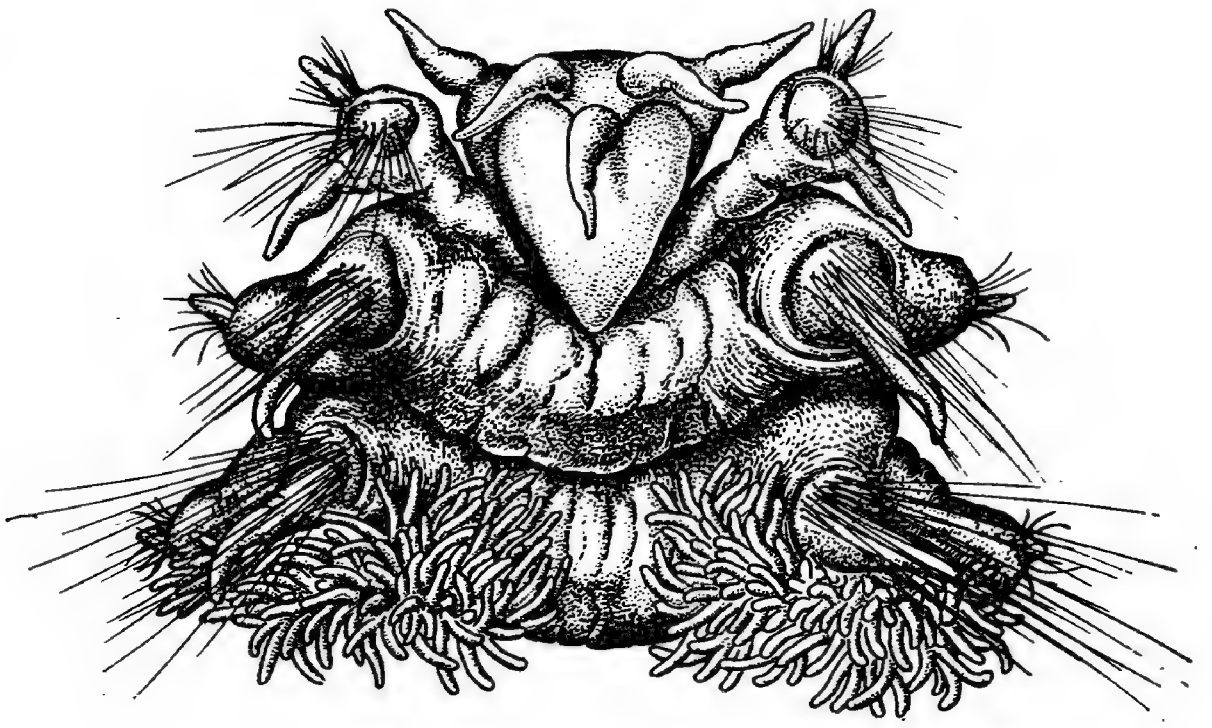
Plate 5, fig. 1

Aphrodita carunculata Pallas, 1766, pp. 102–106, pl. 8, figs. 12, 13.

Hermodice carunculata Mullin, 1923, pp. 44–45, pl. 5, figs. 2–3; Monro, 1933, p. 245.

This, like the preceding, is associated with floating or drifting objects in warm currents. It is recorded from southern Florida by Mullin (1923) and Monro (1933).

The body is long, vermiform, in size approaching that of *Amphinome rostrata* (see above); a large specimen may be 12 inches long but most are smaller. The prostomial caruncle is large and extends back to the third or fourth segment; it is transversely folded (pl. 5, fig. 1). Branchiae are large and bushy, present from the first segment and continued back through the body.



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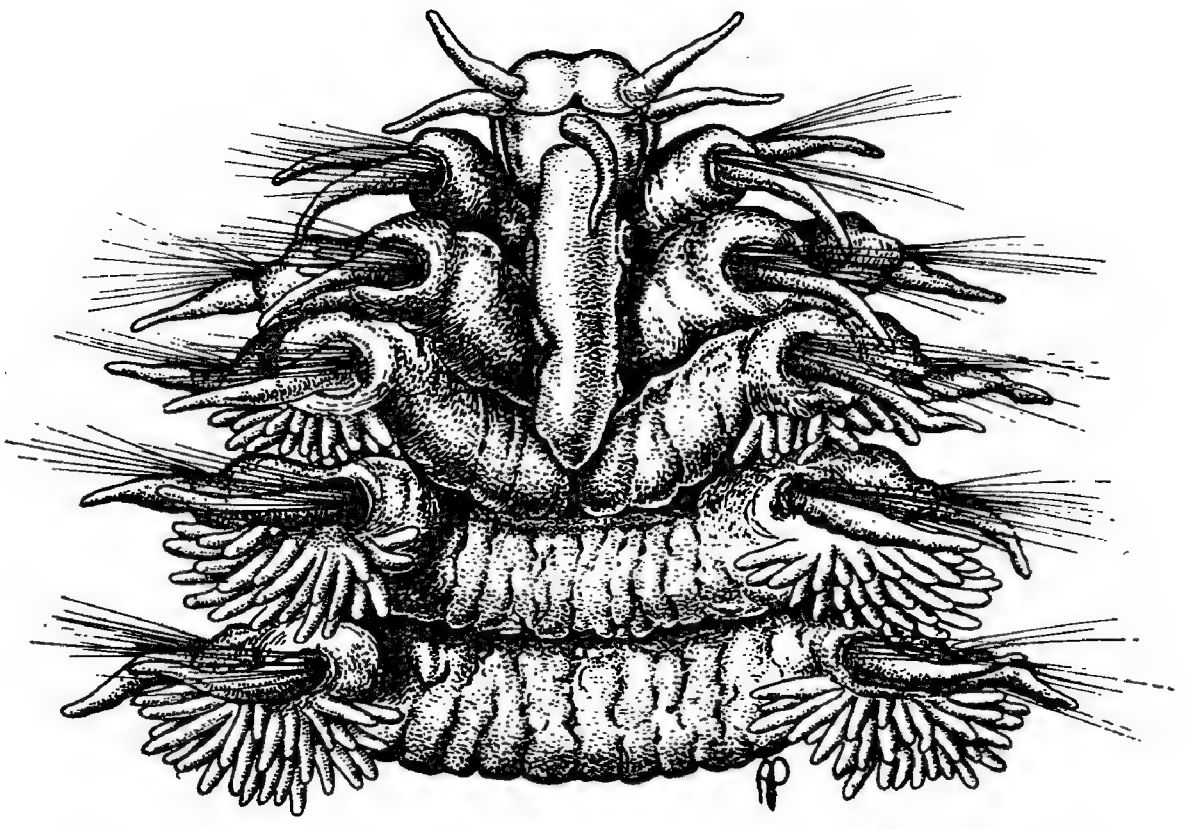

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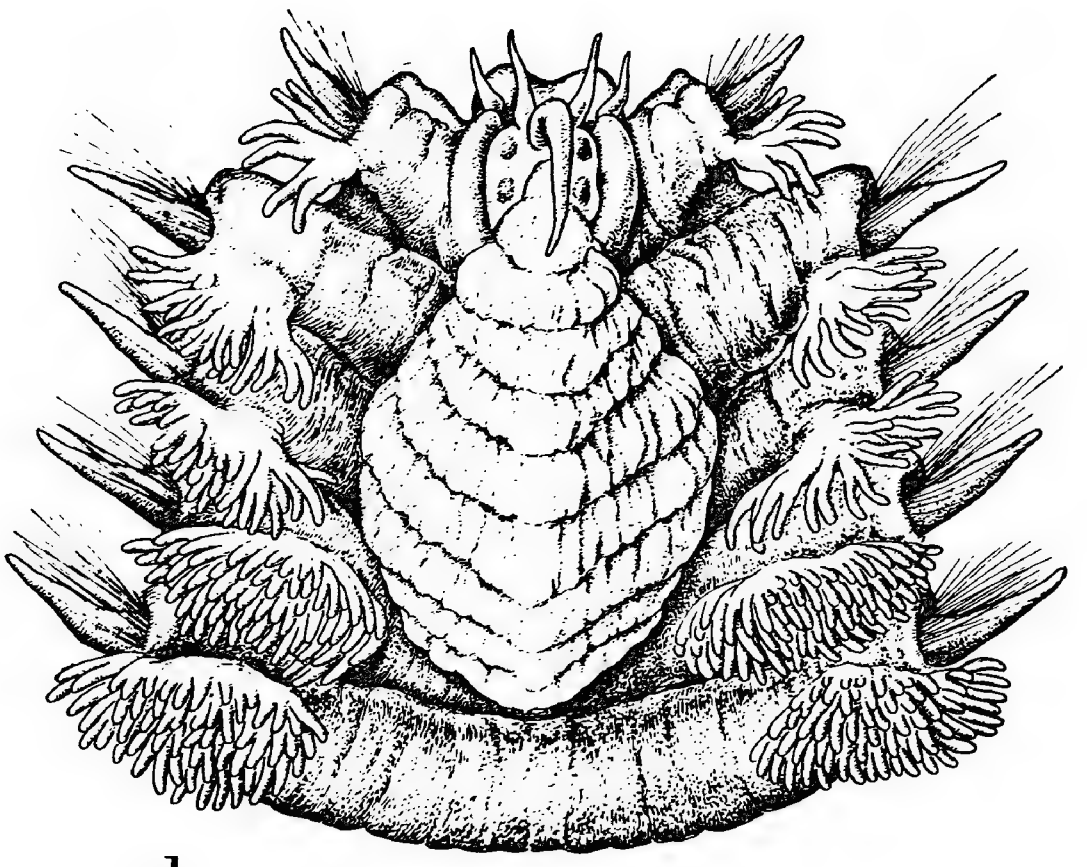
PLATE 4

FIG. 1. *Amphinome rostrata* (Pallas), anterior end in dorsal view, x 15.
FIG. 2. *Eurythoë complanata* (Pallas), anterior end in dorsal view, x 17.

In life the body is greenish to chocolate brown, the branchiae are bright red and the ventrum is pale. Preserved these colors fade. The characteristic over-all features are shown in photographs by Mullin (1923, pl. 5).



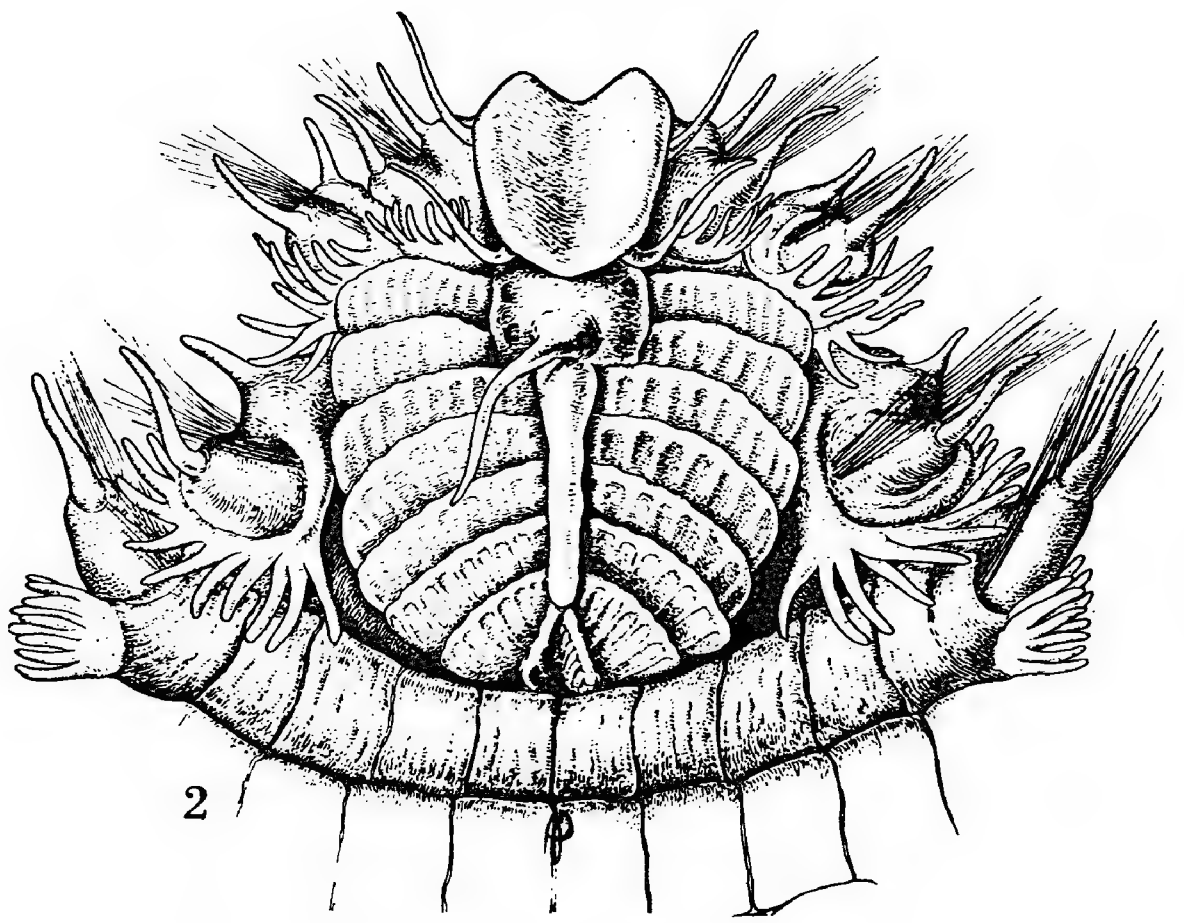


PLATE 5

FIG. 1. *Hermodice carunculata* (Pallas), anterior end in dorsal view, x 8.5.
FIG. 2. *Pherecardia striata* (Kinberg), anterior end in dorsal view, x 17.

This species occurs commonly in littoral zones of tropical parts of eastern America and into the eastern parts of the Gulf of Mexico. There are as yet no records of its occurrence in the western end.

Another amphinomid which might be confused with the preceding species is *Pherecardia striata* (Kinberg), widely known from tropical seas. The characteristic prostomial caruncle (pl. 5, fig. 2) readily distinguishes it from all others. Although not yet collected from the Gulf of Mexico, it may well be expected to occur.

Eurythoë complanata (Pallas), 1766

Plate 4, fig. 2

Aphrodita complanata Pallas, 1766, pp. 109–112, pl. 8, figs. 19–26.

Eurythoë complanata Monro, 1933, p. 245; Hartman, 1940, pp. 202–203, pl. 31, figs. 1–4.

This occurs in the eastern parts of the Gulf of Mexico, especially in rocky or coralline areas, creeping over and under stones in littoral zones.

The body is long, 10 to 16 inches or shorter, vermiform and only slightly depressed. The prostomial caruncle (pl. 4, fig. 2) is dorsally flattened and extends back to the third or fourth segment; at its sides it is furrowed. The 4 prostomial eyes are conspicuous and arranged in a rectangle. Branchiae are large and bushy; they are present from the second segment and continued back to the end of the body. Color in life is orange yellow with bright red branchiae.

This is well known from both sides of tropical America and in the Pacific Ocean northward to southern California; it occurs in littoral zones. It is not yet known from the western half of the Gulf of Mexico.

Pareurythoë americana, new species

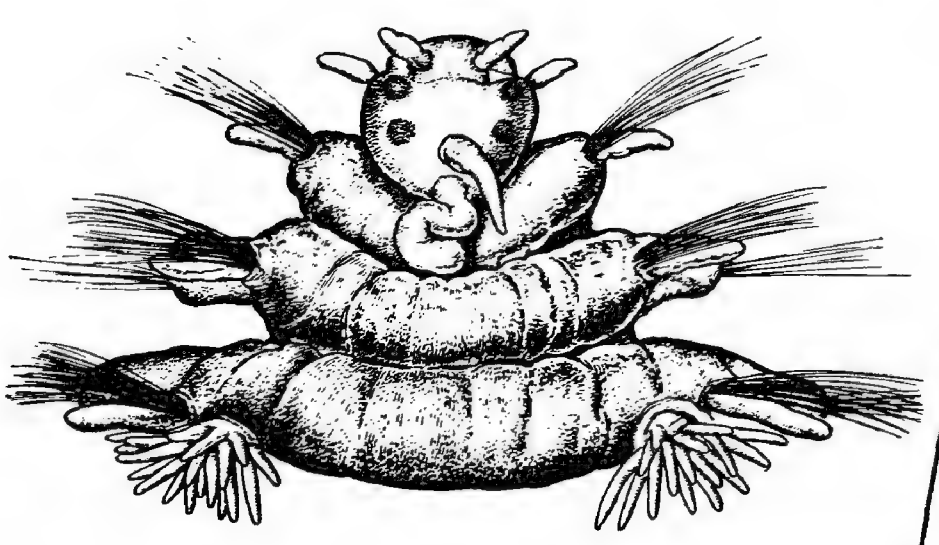
Plate 6, figs. 1–4; Plate 7, figs. 1–4

?Eurythoë dubia Monro, 1933, pp. 5–6, fig. 1. *Not* Horst, 1912.

Several specimens come from Texas and eastern Florida. The holotype (in U.S. Nat. Mus.) is from near St. Lucie Inlet, near Miami, Florida; it is selected because its prostomial parts are more clearly distinguishable and since it is mature. Others come from Padre Island, Texas, July, 1933 (coll. C. T. Reed) and Port Aransas, Texas, Dec. 1947 (coll. J. W. Hedgpeth).

Length of a mature female consisting of 132 segments is 224 mm., width is 11 mm. without, 21 mm. with setae at the anterior third or widest part of the body. The prostomium (pl. 6, fig. 1) is typical for species of the genus *Pareurythoë* Gustafson and closely resembles that shown for *Eurythoë dubia* Monro (1933, fig. 1) except that the caruncle is more conspicuous, due, I believe to varying stages of contraction. Branchiae are first present from the third segment, already bushy and continued large and full to the posterior end of the body. The prostomium is small and approximately chordate; it has 4 large, dark, subequal, circular eyes in quadrate arrangement. The caruncle is slender, sinuous, extends back to the posterior margin of the first segment.

Notosetae are in thick tufts; they project stiffly out at the sides of the body; each is fine, long, white, distally spinous along the outer edge. Neurosetae are similarly in full, strong tufts; each seta is slightly thicker and darker than notosetae. Furcate



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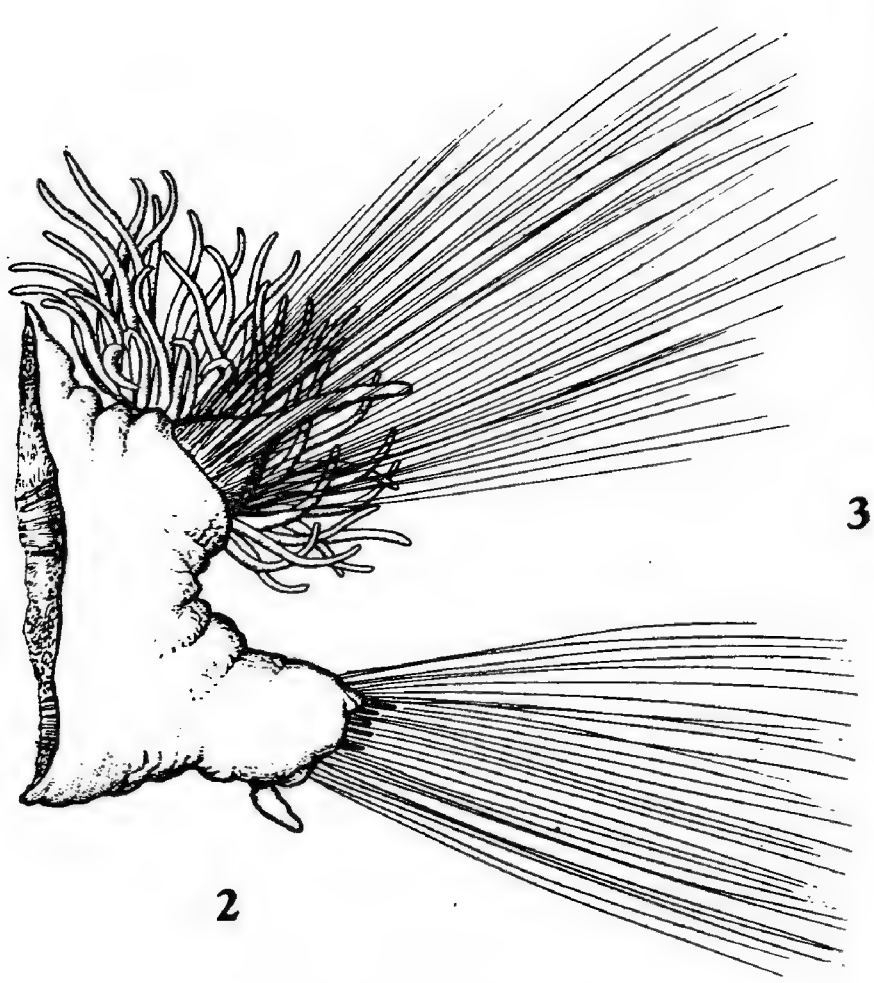

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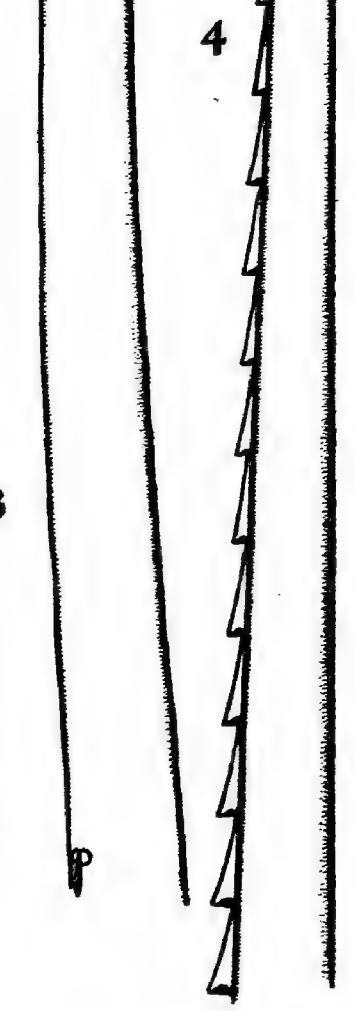

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PLATE 6

FIGS. 1 to 4, *Pareurythoë americana*, n. sp.
FIG. 1, anterior end in dorsal view, x 16.4.
FIG. 2, ninth parapodium in anterior view, x 12.7.
FIG. 3, furcate spine from a median parapodium, x 511.
FIG. 4, distal end of a notopodial harpoon seta, x 775.

spines (pl. 6, fig. 3) are present and accompany the setae in all segments in both notopodia and neuropodia. They are inconspicuous because of their small size but can be found in the anterior part of the fascicle in single vertical series. The degree

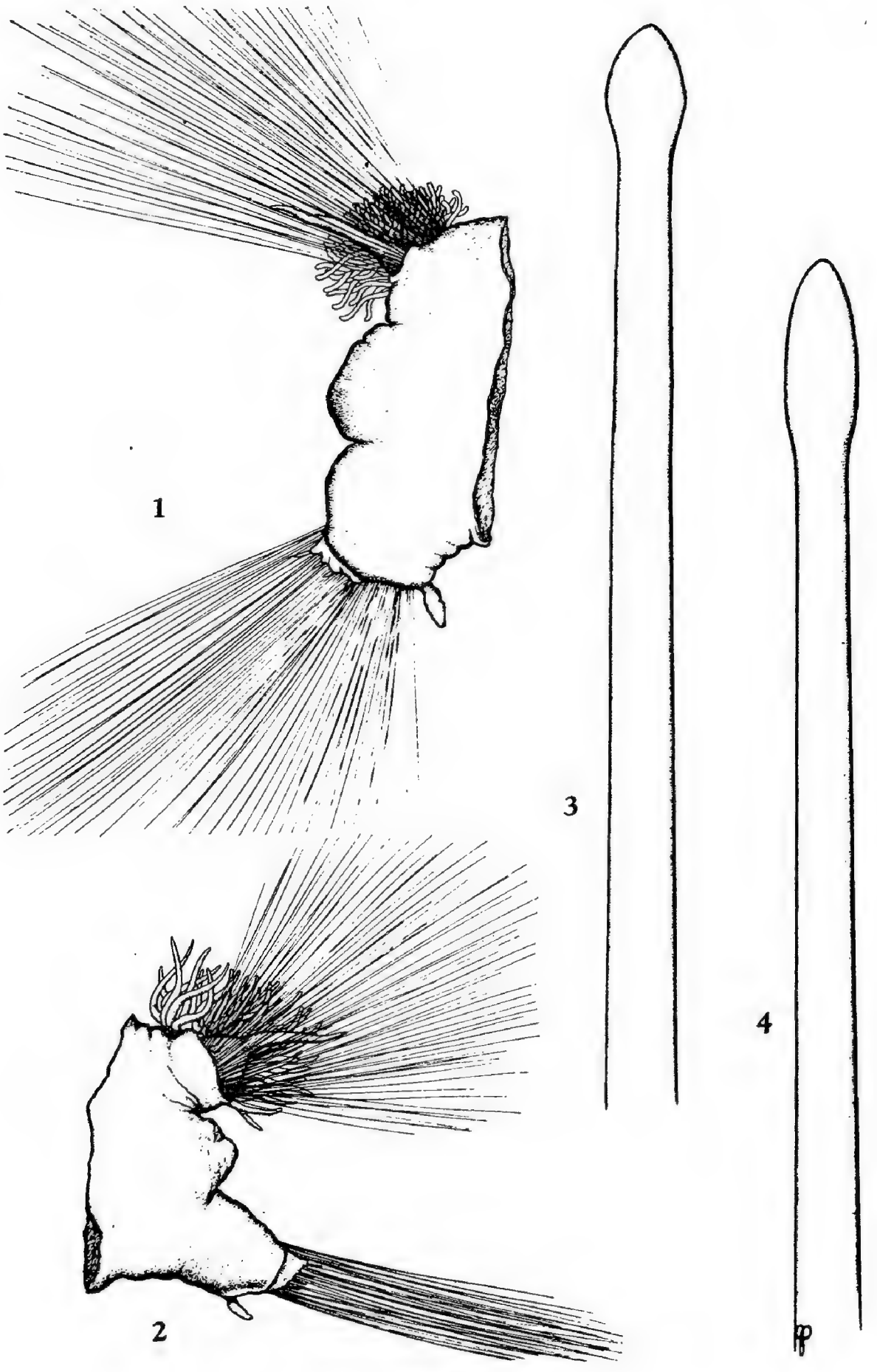


PLATE 7

FIGS. 1 to 4, *Pareurythoë americana*, n. sp.
FIG. 1, fifty-fourth parapodium in anterior view, x 10.7.
FIG. 2, a far posterior parapodium in anterior view, x 10.7.
FIG. 3, distal end of an anterior aciculum, x 630.
FIG. 4, distal end of a posterior aciculum, x 630.

of furcation is greatest for setae in front and diminishes in segments farther back. Acicula are present in vertical series of several in a row in both notopodia and neuropodia; they are straight rods, distally thickened as a prolonged knob; the knob is shortest (pl. 7, fig. 3) in front and increases in length going back (pl. 7, fig. 4).

Harpoon setae (pl. 6, fig. 4) are present but inconspicuous in notopodia; they are no thicker than the hairlike setae and much shorter; their serrations are directed downward.

The ventral cirrus is short on the ninth (pl. 6, fig. 2) or a typical segment with its length/width ratio about 3 to 1. Dorsal cirri are much longer and resemble the accompanying branchial filaments but are somewhat thicker. The dorsal cirrus is about twice as long as the ventral one; it continued large through median (pl. 7, fig. 1) and posterior segments (pl. 7, fig. 2).

A specimen from Padre Island, Texas is large, ovigerous, measures 152 mm. long and has more than 100 segments. The prostomial caruncle is completely withdrawn into the fold of the first segment so as to be invisible; by dissection medially into the first 2 segments its parts are clearly seen. The caruncle is slender, sinuous, just as in the specimen from Stuart Inlet. It extends back to the posterior margin of the first segment. The fully exposed prostomium is crest-shaped and has 4 large eyes in quadrate arrangement. Branchiae are present from the third segment and continued back to the end of the body. Notosetae are fine, white; neurosetae are thicker and pale yellow.

Another specimen from Port Aransas, Texas has the caruncle also withdrawn into the first 2 segments but it can be seen by dissection. The anterior eyes seem to be much larger than the posterior ones but the latter are pushed to the side and thus seen only in lateral view.

P. americana differs from other species of the genus *Pareurythoë* Gustafson most clearly for having its setae consist largely of slender, hairlike ones with furcate spines present but inconspicuous. The harpoon-like setae are also limited in number and size.

P. americana is known only from eastern sandy beaches of Florida and from Texas. Another species belonging to the genus comes from Puerto Rico and was named *Hipponoë elongata* Treadwell (1931, pp. 3–4, figs. 10–12). This is known only through its original account. The statement that there is no caruncle should probably read that the caruncle is withdrawn or retracted. I surmise that it is short and slender and resembles that of other species of *Pareurythoë*. It is a large species, to 185 mm. long and 8 mm. wide. The prostomium has 4 eyes in quadrate arrangement, and 3 antennae. Branchiae are first present from the third segment, bushy, dendritically branched and continued back to the end of the body. The anal aperture is at the extreme posterior end. The first segment has conical dorsal and ventral cirri and small tufts of neurosetae and notosetae. In median segments the dorsal cirrus is prominent and the setal tufts protrude from oval depressions. Ventral cirri are small. Notosetae are long, slender and pointed. Neurosetae are in dense tufts, all similar in form except for a few which are larger than the others and each of these has a short, blunt, marginal tooth beyond which the seta tapers to a blunt point. This species is here newly combined as *Pareurythoë elongata* (Treadwell).

Hipponoë multibranchiata (Treadwell), revised

Plate 8, figs. 1, 2

Metamphinome multibranchiata Treadwell, 1940, pp. 1–2, figs. 1–3.

Through the courtesy of the American Museum of Natural History I have examined the holotype specimen from Galveston, Texas from a floating log.

The body is short, fusiform, broadest in the middle and it tapers to both ends; it is depressed with both dorsum and ventrum broadly exposed. Its length (mature) is 20 mm. and it consists of 28 segments. The prostomium is plainly visible; it is rounded in front, has 4 subequal, paired antennae and a longer, median unpaired one; there are no eyes. The caruncle is represented by a minute, button-like process at its postmedian margin (fig. 1). Branchiae are present from the third segment with 3 filaments, located behind the notosetal fascicle; they are continued back to the posterior end. The flat ventral side has paired series of strong, falcate hooks (fig. 2) with 3 or more in a series, located about half the distance between the side and the midventrum, as in *Hipponoë gaudichaudi* (Audouin and M. Edwards) (see Fauvel, 1923, p. 132, fig. 47). Notosetae are long and slender to hairlike and arranged in close tufts.

This species is here newly referred to *Hipponoë* Audouin and M. Edwards with which it agrees in its fusiform body, kinds of setae, branchial parts and prostomium. *H. multibranchiata* differs from *H. gaudichaudi* for lacking eyes instead of having them, for having a caruncle which is greatly reduced, and for the continuation of branchiae to the posterior end. The species is known only from Galveston, Texas.

Chloeia viridis Schmarda, 1861

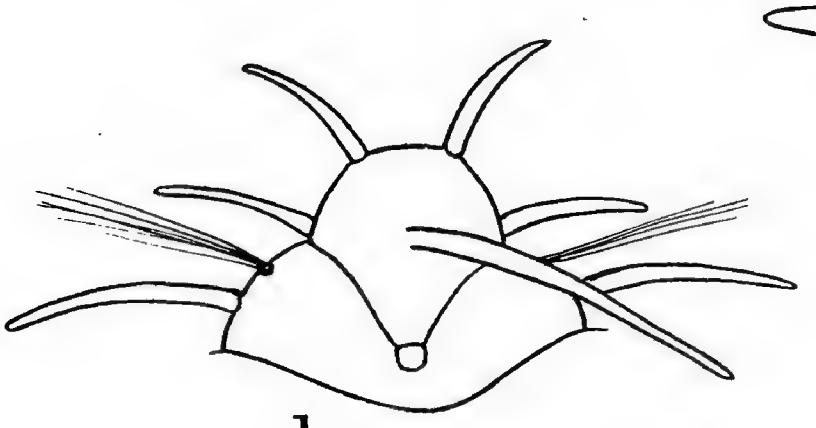
Chloeia euglochis Ehlers, 1887, pp. 18–24, pl. 1, figs. 1, 2, pl. 2, figs. 1–8, pl. 3, figs. 1–4 (colored plate).

This comes from southern Florida in littoral zones, associated with reefs. The body is short, broad, depressed, glistening white due to the conspicuous glass-like bristles. Length reaches 20–30 mm. The dorsal side of the body is conspicuously striped (see Ehlers, plate 1) with red and brown bars.

The species occurs widely in West Indian seas and in the eastern part of the Gulf of Mexico.

Family PHYLLODOCIDAE

The phyllodocids are short to long, often brilliantly iridescent or opalescent, mucous secreting, errantiate worms, sometimes occurring in aggregated masses, or solitary, in crevices, under stones, or with other organisms such as oysters, commonest in intertidal zones. Characteristic features are the eversible cylindrical proboscis which has a papillar crown at its distal end, lacks jaws, and its outer surface may be papillated or smooth. Parapodia are uniramous and have foliaceous dorsal cirri. Setae are entirely composite and distally pointed. (See Fauvel, 1923, pp. 143–144 for illustrated keys to genera.)



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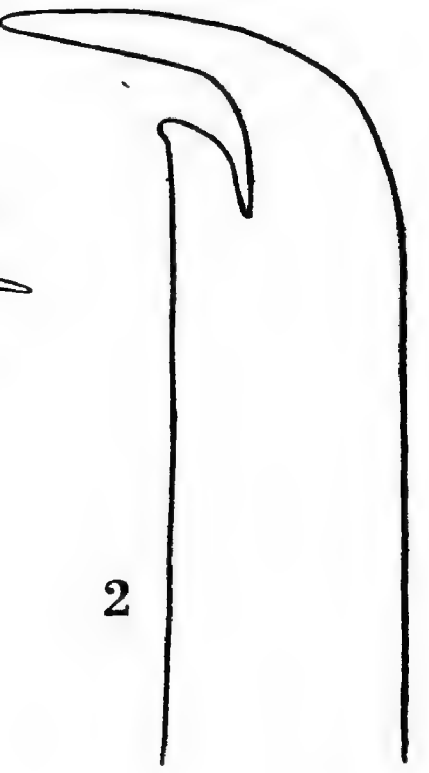

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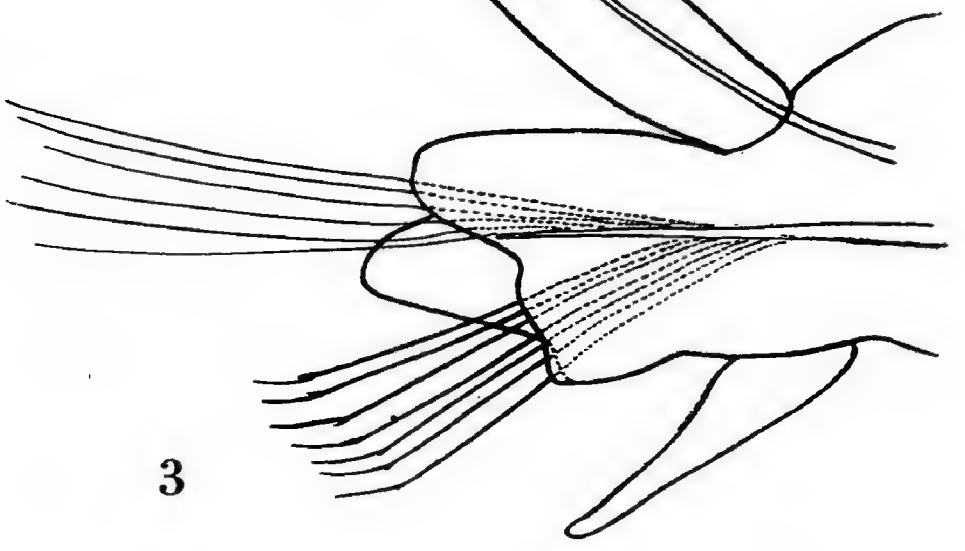

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PLATE 8

FIGS. 1, 2, *Hipponoë multibranchiata* (Treadwell).

FIG. 1, anterior end in dorsal view, x 22.

FIG. 2, a neuropodial hook from a median segment, x 580.

FIGS. 3 to 6, Species of *Dorvillea*.

FIG. 3, *Dorvillea sociabilis*, a median parapodium in anterior view, enlarged.

FIG. 4, *Dorvillea rubra*, a neuropodial hook from a median segment, much enlarged.

FIG. 5, *Dorvillea sociabilis*, a neuropodial hook from a median segment, much enlarged.

FIG. 6, *Dorvillea rudolphii*, a neuropodial hook from a median segment, much enlarged.

Key to Species

1. With 4 pairs of tentacular cirri 2
1. With 2 pairs of tentacular cirri 6
2. Prostomium with a median antenna 3
2. Prostomium without a median antenna 4
3. Proboscis with papillae strewn over the surface; body long, slender, to 12 inches and the dorsum longitudinally striped ..... *Eulalia myriacyclum*
3. Proboscis without papillae; body short, thick; body uniformly colored green to brown in life ..... *Eumida sanguinea*
4. Prostomium small, quadrate, without a nuchal papilla at its postmedian margin.... 5
4. Prostomium larger, chordate, with a small nuchal papilla at its postmedian margin; body larger, to 6 inches long ..... *Anaitides erythrophyllus*
5. Dorsal cirri thick; ventral cirri small and thick; eyes with lenses ..... *Nereiphylla fragilis*
5. Dorsal cirri thin and foliaceous; ventral cirri extend distally beyond setigerous lobes; eyes lack visible lenses ..... *Nereiphylla* near *paretti*
6. Dorsal cirri asymmetrical (pl. 9, fig. 4) ..... *Eteone heteropoda*
6. Dorsal cirri symmetrical or nearly so ..... *Eteone alba*

Eteone heteropoda n. sp.

Plate 9, figs. 1–8

Many come from Stingaree Flats, upper end of Lemon Bay, Florida, Jan. 1938, Ochlockonee Bay, Franklin Co., Florida, March 1950 (coll. L. M. Henry), Deer Island, near Biloxi, Mississippi, 1943 (coll. M. W. Williams), and Rockport, Texas, shore, Dec. 1945 (coll. J. W. Hedgpeth); all come from sandy muds in sloughs, estuaries or intertidal habitats.

Length of a larger, mature individual is 93 mm., number of segments is over 178. Others somewhat smaller though also mature measure 50 to 60 mm. long and have 140 to 170 segments. The body is long, slightly depressed, except for the laterally projecting parapodial lobes that come to be increasingly conspicuous in posterior segments. The color of the body in life is pale yellow or greenish, with dorsal cirri and anal appendages darker than the dorsum and the ventrum palest. Preserved individuals are pale to white to somewhat brown.

The prostomium is trapezoidal in outline, seen from above, with length and width about equal. The narrower, anterior margin has 2 pairs of biarticulate antennae (fig. 1) and the longer, posterior margin is straight or slightly arcuate when the proboscis is everted; at its midpoint there is a minute, papillar nuchal organ. A pair of small, dark, simple eyespots can be distinguished on the posterior half of the prostomium.

The proboscis when everted is somewhat cylindrical except for a slightly thickened distal end (fig. 1); its proximal surface is smooth except for wrinkles of contraction, and the longitudinal furrows that indicate the position of the underlying muscular attachments; the distal end terminates in 19 subglobular papillae that are arranged in a complete circlet (fig. 1).

The first segment is longer than those following; it has 2 pairs of tentacular cirri; the dorsal ones are slightly slenderer and shorter than the ventral pair but the 2 resemble each other (fig. 1). The second segment is the first setigerous; its parapodia are like those farther back but they lack dorsal cirri. In anteriormost segments the dorsal cirri are subtriangular and nearly symmetrical (fig. 3); farther back in median

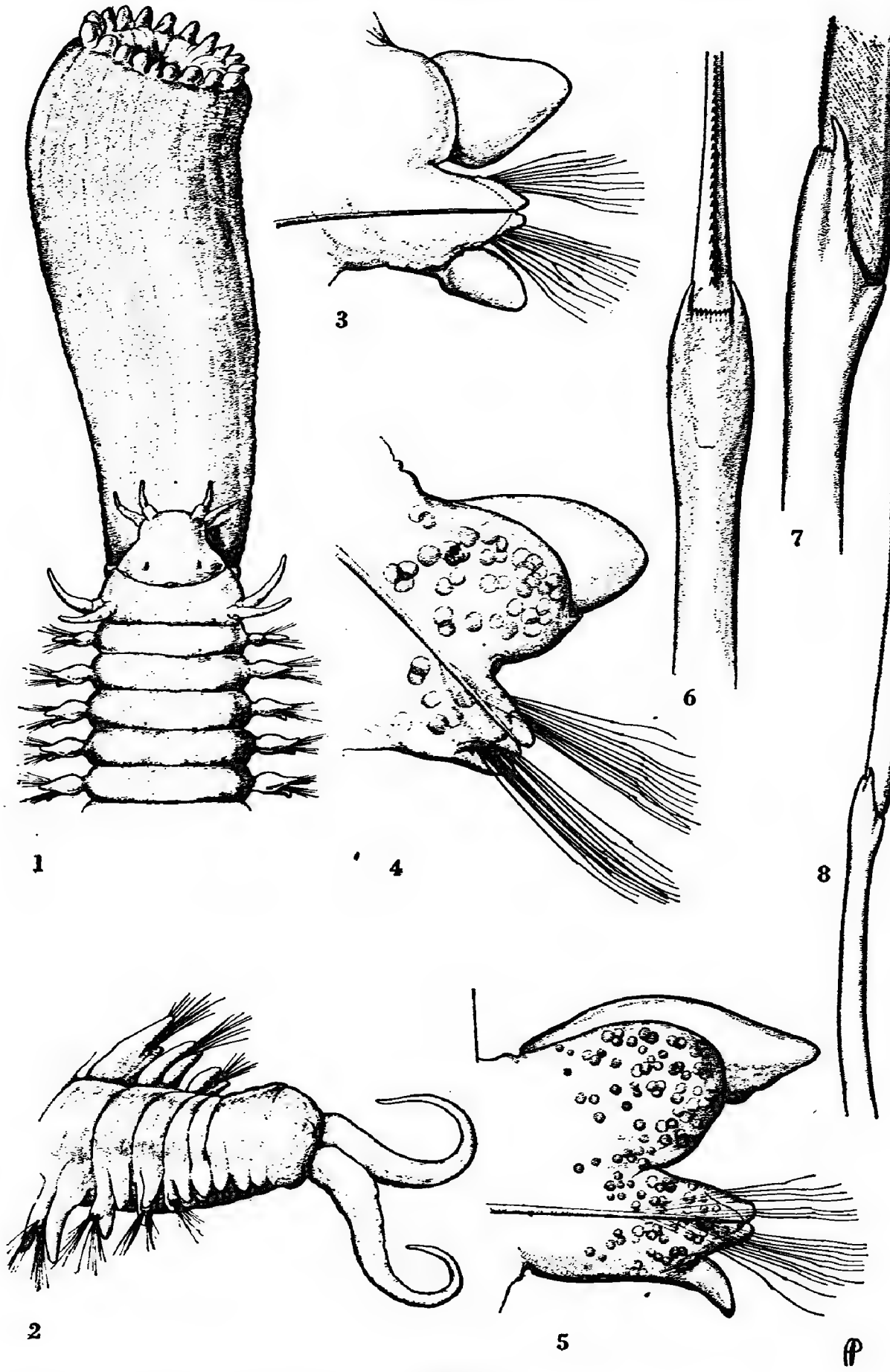


PLATE 9

FIGS. 1–8. *Eteone heteropoda*, n. sp.

FIG. 1, anterior end with everted proboscis, in dorsal view, x 14.

FIG. 2, posterior end including last few segments and pygidium, seen from the left side, x 54.

FIG. 3, sixth parapodium in anterior view, x 54.

FIG. 4, sixtieth or median parapodium in anterior view, with some of the ova seen through the body wall, x 38.

FIG. 5, a far posterior parapodium in anterior view, with ova seen through the body wall, x 38.

FIG. 6, articulating shaft and appendage from a seta, seen from the cutting edge, x 977.

FIG. 7, articulating shaft and appendage seen from the side, x 977.

FIG. 8, composite seta from a median parapodium seen from the side, x 350.

(fig. 4) and posterior (fig. 5) segments the dorsal cirrus comes to be very asymmetrical so that its superior edge is far longer than its inferior one.

Ventral cirri extend well beyond the setigerous lobe in anterior segments; in median and posterior segments they are surpassed by other parapodial parts (figs. 3 to 5). The setigerous lobe consists of a bifid presetal part and a shorter, distally rounded postsetal lip.

Setae are entirely composite, arranged in supra- and subacicular fascicles. Together they form a fan-shaped series. They number 18 to 25 in a parapodium. Each consists of a thicker shaft and a tapering, distally pointed appendage (fig. 8). The shaft is distally oblique and has a sharp tooth (fig. 7) on each side. The cutting edge of the appendage is provided with a single row of short spinelets (fig. 6). Acicula occur singly in parapodia. They are straight slightly distally tapering rods and project from the bifid presetal lobe or are entirely embedded.

The posterior end tapers to a slender, unarmed tail; the last 5 to 10 segments are poorly marked and lack setae but their parapodial lobes are distinguishable (fig. 2); the anus is terminal and has a pair of long, tapering, fleshy appendages. Many individuals have large ova, crowded into the dorsal cirrophores, the setigerous lobes and the body cavity; they extend from about segment 40 to the posterior end.

This species is distinguished from others of the genus for having the striking asymmetrical dorsal lobes of parapodia. It is known to occur only in the Gulf of Mexico, from Florida west to Texas, in intertidal sandy flats.

Eteone alba Webster, 1879

Eteone alba Webster, 1879, pp. 106–107; Hartman, 1945, p. 14, figs. 5, 6.

One comes from Ocklockonee Bay, Franklin Co., Florida, March 1951 (coll. D. Carpenter). It is pale (preserved) and measures 38 mm. long. The 2 pairs of tentacular cirri are very unequal in size with the dorsal less than half as long as the ventral ones. The species occupies sandy beaches; it is elsewhere known from eastern United States to North Carolina (Hartman, 1945).

Anaitides erythrophyllus (Schmarda), 1861

Phyllodoce oculata Ehlers, 1887, pp. 135–140, pl. 40, figs. 4–6.

Phyllodoce tortugae Treadwell, 1917, p. 262, pl. 2, figs. 4–6.

Phyllodoce (Anaitides) oculata Monro, 1933, p. 247.

This comes from southern Florida, associated with reefs. It is a long, slender form attaining a length of 100 mm. or more. In life as well as preserved it is diffusely dark above and paler at the sides. Ventral and dorsal cirri are thin and foliaceous.

The species occurs commonly in West Indian littoral seas and in the eastern end of the Gulf of Mexico; it is not yet known from the western Gulf.

Eulalia myriacyclum (Schmarda), 1861

Notophyllum myriacyclum Schmarda, 1861, p. 87, pl. 29, fig. 233.

Eulalia quinquelineata Treadwell, 1901, p. 192, figs. 27–29.

This comes from reefs of southern Florida and Alligator Reef, Franklin Co., Fla., March, 1951 (coll. R. Miles). It is a very long, slender, strikingly marked species. Length attains 100 mm. or more. The dorsum has 5 dark longitudinal stripes throughout its length. The species is known from the West Indies and eastern part of the Gulf of Mexico.

Eumida sanguinea (Oersted), 1843

Eulalia (Eumida) sanguinea Fauvel, 1923, pp. 166–167, fig. 59.

Eumida sanguinea Hartman, 1945, p. 14.

Specimens come from Lemon Bay, southwestern Florida. In life the body is green to brown, short thick, to 40 mm. long. Individuals are associated with detritus in littoral zones. The species is cosmopolitan in temperate seas.

Nereiphylla fragilis (Webster), 1879

Phyllodoce fragilis Webster, 1879, pp. 214–215, pl. 3, figs. 32–37.

?Phyllodoce unicirrata Winternitz, 1936, pp. 1–2, figs. 3–5.

Nereiphylla fragilis Hartman, 1945, p. 14, pl. 2, figs. 1–4.

There are collections from Lemon Bay, Florida trawled in the pass, from Grove City Key, Florida and from Alligator Harbor, Franklin County, Florida; others are from Port Aransas, Texas in oyster clumps. Specimens often occur in aggregated masses in oyster masses or in crevices. The body is long, slender, tapers forward to a very minute rectangular prostomium and a slender tail. There are 2 large circular eyes on the prostomium, each has a pale circular lens. Tentacular cirri are clavate to cirriform. Dorsal cirri are diffused deep purple (preserved), thick, tumid and cordiform in outline. The anterior ones resemble those farther back. Ventral cirri are likewise thick and surpassed in length by their respective setigerous lobe, except in younger specimens where the ventral cirri are comparatively larger. Anal cirri are thick and clavate.

Phyllodoce unicirrata Winternitz (1936, pp. 1–2, figs. 3–5) from Apalachicola, Florida is questionably referred to *Nereiphylla fragilis* Webster. The composite setae are erroneously shown as simple ones; the articulation was probably overlooked.

Webster (1879, p. 215) described the color in life as head greenish white, body light to dark green; all cirri yellowish green; body and dorsal cirri with many dispersed dark brown spots.

Nereiphylla fragilis occurs throughout the Gulf of Mexico and elsewhere from Virginia to Florida; its commonest association is with oyster clumps.

Nereiphylla, near *paretti* Blainville, 1818

Phyllodoce paretti Fauvel, 1923, pp. 154–155, fig. 55.

Some collections from Lemon Bay, Florida and vicinity, in intertidal and trawled materials, differ from the preceding, *N. fragilis* (Webster); they approach the European *Nereiphylla paretti* Blainville. Color in life is deep yellow; preserved the yellow changes to orange red with the dorsal cirri lightly speckled with dark pigment.

The number of segments is about 130; the body is long and tapers to both ends as in *N. fragilis*. The prostomium is small, quadrate, has 2 large dark eyes that lack a lens. Dorsal cirri are large, thin and foliaceous throughout. Those in front are cordiform, farther back they are longer and come to be narrow, lanceolate. Ventral cirri are likewise much larger than comparable ones in *N. fragilis*. Anal cirri are clavate to cirriform, their length equal to that of the last 8 segments, or in other individuals they are shorter to less than half that long.

These specimens differ from descriptions of the Mediterranean species in that anal cirri are not foliaceous but cylindrical to clavate; tentacular cirri are only very slightly depressed instead of considerably so.

This species occurs with *N. fragilis* in eastern parts of the Gulf of Mexico and is associated with ascidian masses.

Family HESIONIDAE

Except for their much smaller size, the hesionids are similar to members of the PHYLLODOCIDAE; in life they tend to be highly colored. Only 2 species have been identified from the Gulf of Mexico.

Key to Species

1. Anterior end with 6 pairs of tentacular cirri; prostomium with 3 antennae (pl. 10, fig. 1) ..... *Podarke*, near *guanica*

1. Anterior end with 8 pairs of tentacular cirri; prostomium with 2 antennae ..... *Hesione picta*

Hesione picta Müller, 1858

Hesione picta Müller, 1858, p. 213, pl. 6, fig. 3.

Hesione proctochona Schmarda, 1861, pp. 79–80, pl. 28.

Hesione vittata Ehlers, 1887, pp. 143–147, pl. 41 (colored).

Specimens come from southwestern Florida in rocky habitats. The body is short, depressed rectilinear, 30 to 50 mm. long and consists of about 16 segments. The 8 pairs of tentacular cirri are very long, slender and extend far out at the sides of the body.

In life the body is dark, crossed by ivory colored stripes; tentacles and dorsal cirri are reddish brown. The striking contrasts are shown in color by Ehlers (1887, pl. 41).

I regard the Brazilian *Hesione picta* Müller the same as *H. vittata* Ehlers from southern Florida and *H. proctochona* Schmarda from the West Indies. The first name has priority.

Hesione picta thus ranges throughout the tropical west Atlantic and into the eastern end of the Gulf of Mexico.

Podarke, near *guanica* Hoagland, 1919

Plate 10, figs. 1–3

Podarke guanica Hoagland, 1919, pp. 571–572, pl. 29, figs. 1–4.

Podarke obscura Hartman, 1945, pp. 14–15; *not* Verrill, 1873.

This comes from southwestern Florida on muddy sand flats, among spines of the sea urchin, *Lytechinus* and in old snail shells. The body is short, 10 to 22 mm. long and consists of 35 to 38 segments. In life the color is purplish brown to almost black, with 4 red eyes; the ventrum is pale. The prostomium (fig. 1) is quadrate, broader than long and has 3 antennae, the paired ones are longer and inserted in front; the much shorter median one is inserted between the paired ones. Paired palpi are immediately to the sides of the antennae; they resemble the longer antennae in size and shape but are connected to the oral ring or peristomium. The 4 eyes are large, circular, in quadrate arrangement; the anterior ones are the larger and wider apart, directed forward; all are lenticulated. They are not as large as those shown by Hoagland (1919, fig. 1) for *Podarke guanica* from Puerto Rico, nor are they located so far forward.

The eversible proboscis is cylindrical and ends in 10 widely spaced short lobes that resemble one another.

Parapodia are similar to those shown by Hoagland (1919, fig. 2) but the notopodium has an aciculum and 2 slender emergent setae; the presetal neuropodial lobe is triangular (fig. 2). In far posterior parapodia (fig. 3) the parapodial base comes to be slenderer but presetal and postsetal parts are similar to those in the middle.

These specimens are nearer *P. guanica* Hoagland than to *P. obscura* Verrill from New England. In the latter the parapodial bases are much longer, the ventral cirrus is greatly prolonged and slender so as to extend beyond the setal lobes and the proboscis lacks terminal papillae. Specimens from Beaufort, North Carolina which I earlier (1945, p. 14) designated *P. obscura* Verrill, agree with those from southern Florida. The range is thus extended northward to North Carolina.

Family PILARGIIDAE

Two representatives of this unique family are known from the Gulf of Mexico.

Key to Species

1. Prostomium with 3 antennae (pl. 11, fig. 2) ..... *Ancistrosyllis bassi*
1. Prostomium without antennae (pl. 12, fig. 1) ..... *Loandalia americana*

Ancistrosyllis bassi Hartman, 1945

Plate 11, figs. 1–6

Ancistrosyllis bassi Hartman, 1947, pp. 501–504, pl. 61.

This comes from southwestern Florida in sandy beaches at low tide line or in shallow depths.

The unique characteristics of anterior end (fig. 2), the extensile proboscis with distal papillae (fig. 1) and parapodial parts readily identify the species. A second

parapodium (fig. 4), a median or typical one (fig. 3), also a large dorsal hook (fig. 6) from posterior parapodia, and a posterior aciculum are shown in detail.

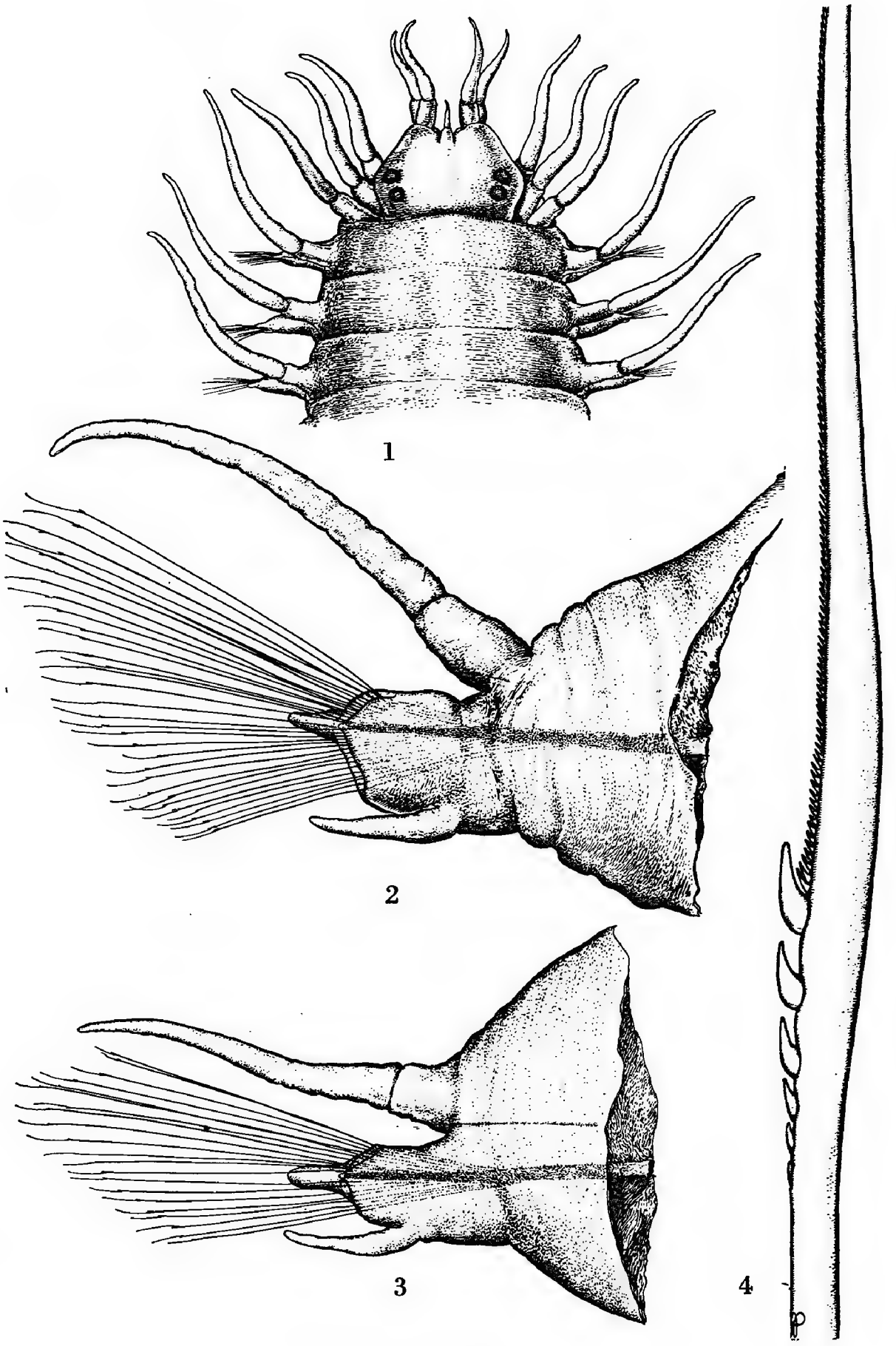
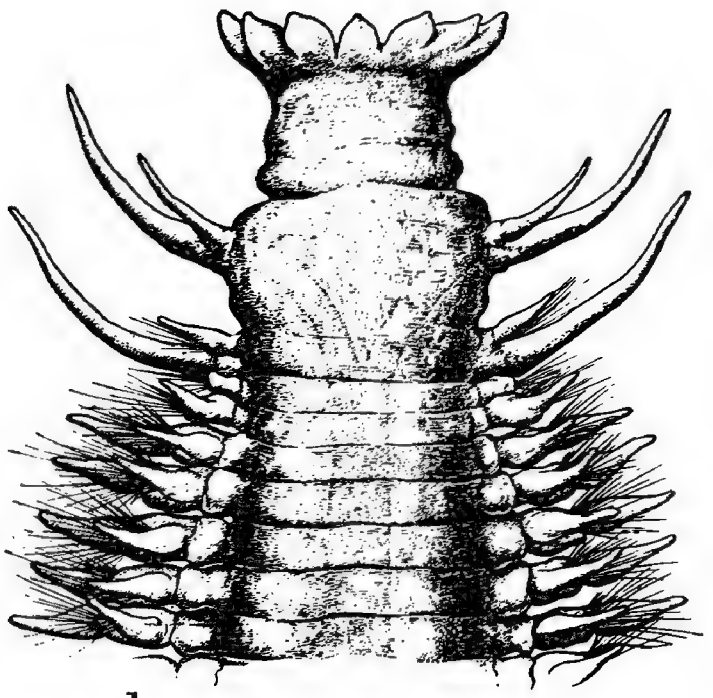


PLATE 10

FIGS. 1 to 3, *Podarke*, near *guanica* Hoagland.
FIG. 1, anterior end in dorsal view, x 35.
FIG. 2, fifteenth parapodium in anterior view, x 21.7.
FIG. 3, a far posterior parapodium in anterior view, x 21.7.
FIG. 4, *Nephtys picta* Ehlers. Spinous region of a middle postacicular seta, x 564.

The species is further known from North Carolina and in San Francisco, California, shore to 10 fms. in sand, but nowhere else.



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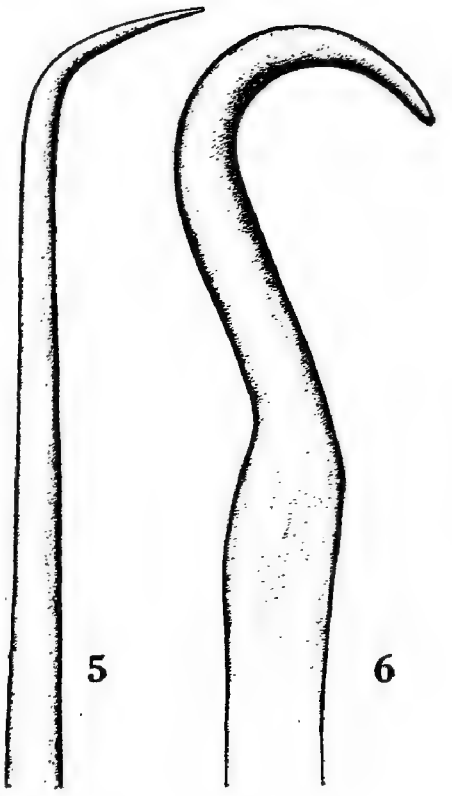

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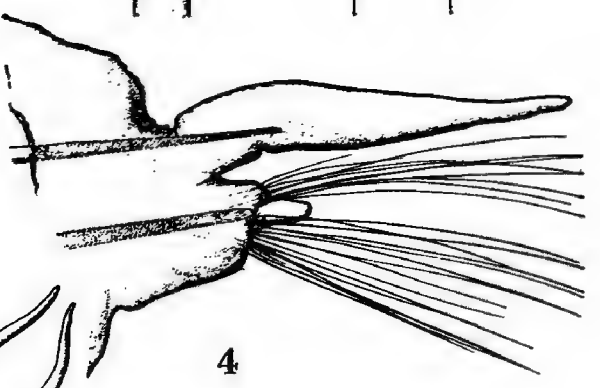

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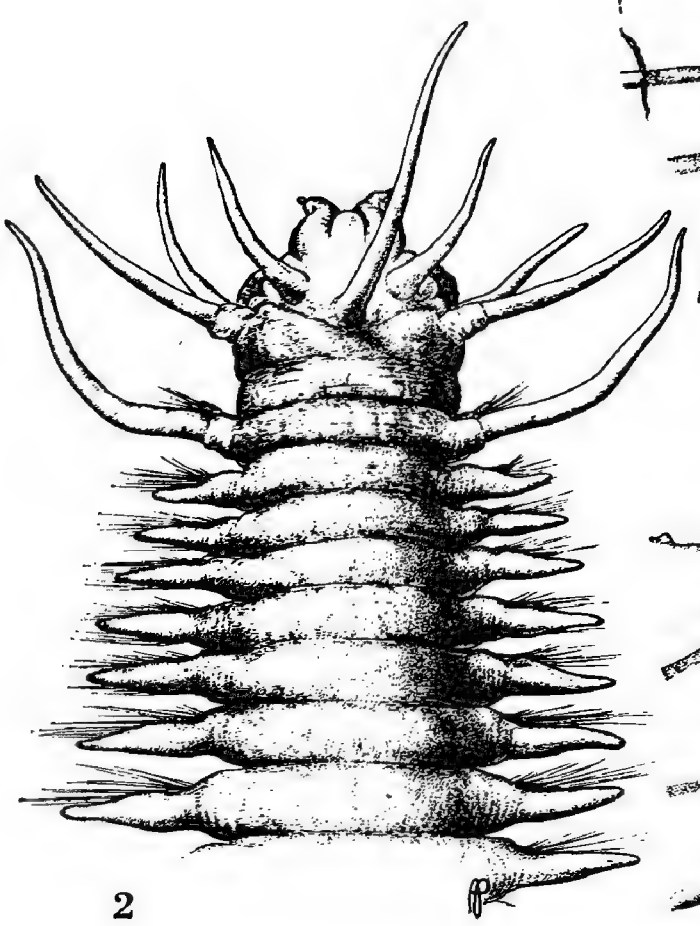

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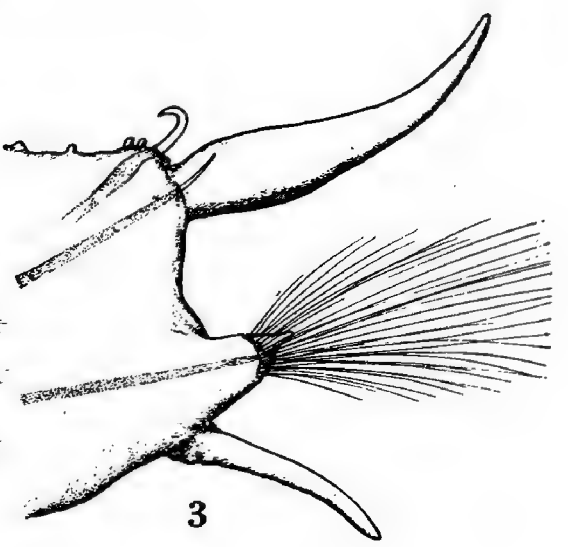

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PLATE 11

FIGS. 1 to 3, *Ancistrosyllis bassi* Hartman.

FIG. 1, anterior end in ventral view, with proboscis everted, x 26.

FIG. 2, anterior end in dorsal view, x 24.

FIG. 3, twentieth parapodium in anterior view, x 72.

FIG. 4, second parapodium in anterior view, x 115.

FIG. 5, a notoaciculum from the fortieth parapodium in lateral view, x 243.

FIG. 6, recurved dorsal spine in lateral view from twentieth last parapodium, x 243.

Loandalia americana Hartman, 1947

Plate 12, figs. 1–3

Loandalia americana Hartman, 1947, pp. 506–509, pl. 63.

Specimens come from Texas, Louisiana and Mississippi in intertidal zones, fine sands. Others come from Oklockonee Bay, Franklin Co., Florida (coll. D. Carpenter). The body comes to be 115 mm. long and has 300 segments or more; it is slender, tapers to a narrow posterior end with an anal plaque (fig. 2). The prostomium is very small and its front end is bifid (fig. 1). Parapodia have small papillar notopodia (fig. 3) and larger neuropodia each provided with simple setae and single acicula.

This species is known only from the Gulf of Mexico and the Pacific side of Guatemala, shore to 13 fms., in sands.

Family SYLLIDAE

Members of this family may be expected in abundance; because of their small size and widely dispersed habitats they have been little collected. Seven species are named below; eight others are named and described by Monro (1933, pp. 246–256) (see above).

Key to Species

(Consult Fauvel, 1923, pp. 254–327 for illustrated keys to genera)

1. Very minute, a few mm. long; palpi entirely fused; ventral cirri present; young segmentally attached to adult female ..... *Exogone dispar*
1. Larger; palpi fused medially only at base or not at all; ventral cirri absent or present; young not segmentally attached 2
2. Ventral cirri absent; dorsal cirri smooth or only wrinkled; anterior cirri much longer than those of other parts of body; sexual stolons greatly modified for epitoky or swimming ..... *Autolytus*, spp.
2. Ventral cirri present 3
3. Dorsal cirri more or less articled or moniliform 4
3. Dorsal cirri smooth, not articled; prostomium partly concealed by a peristomial flap or hood ..... *Odontosyllis enopla*
4. Setae consist entirely of simple ones and are few in a fascicle ..... *Haplosyllis spongicola*
4. Setae include some that are composite 5
5. Body greatly depressed; dorsal cirri with articles that are very numerous and closely crowded; median prostomial antenna inserted at anterior margin of prostomium ..... *Trypanosyllis vittigera*
5. Body not so greatly depressed; dorsal cirri with articles that are not so numerous or crowded 6
6. Composite setae of anterior segments with a greatly prolonged appendage ..... *Ehlersia*, sp.
6. Composite setae of anterior segments without greatly prolonged appendage 7
7. Some median segments have thick Y-shaped simple hooks ..... *Synsyllis longigularis*
7. Median segments have only composite setae ..... *Typosyllis* spp.

Exogone dispar (Webster), 1879

Paedophylax dispar Webster, 1879, pp. 223–224, pl. 4, fig. 49, pl. 5, figs. 50–55.

Exogone dispar Hartman, 1945, p. 16.

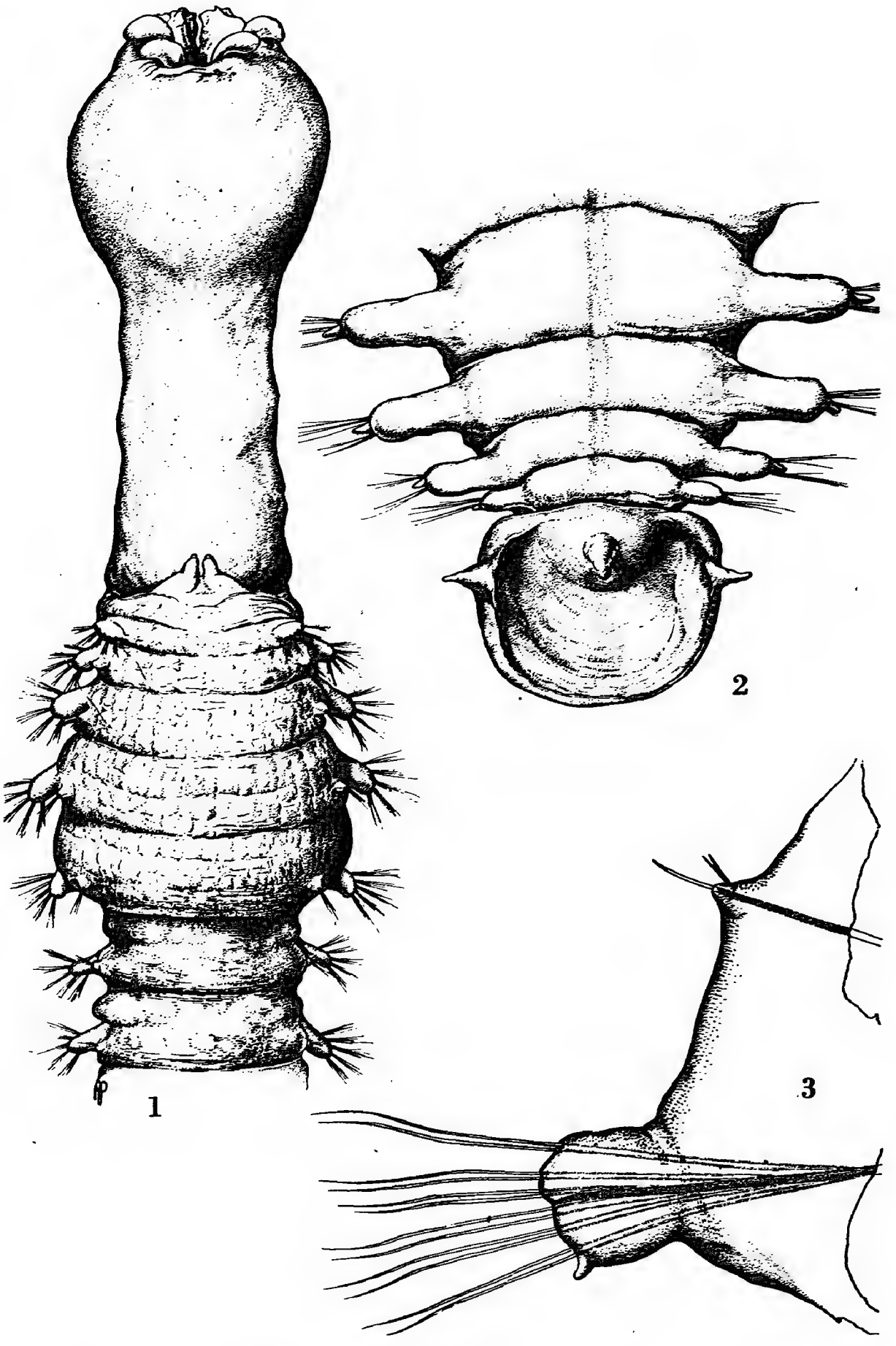


PLATE 12

FIGS. 1 to 3, *Loandalia americana* Hartman.

FIG. 1, anterior end with proboscis everted, in dorsal view, x 22.

FIG. 2, posterior end in ventral view, x 105.

FIG. 3, fiftieth parapodium seen from the front, x 100.

This comes from sponge, ascidian and algal masses from southwestern Florida. Length is 7 mm. at most, and number of segments is 49 or less. The middle prostomial antennae is much longer than the short, stub-like lateral pair. In life the body is white or colorless with a pink tinge. The attachment of ova or juvenile stages on median and posterior segments of the adult occurs in spring.

This occurs more widely from eastern parts of the United States; it may be expected also throughout the Gulf of Mexico but records are still wanting.

Odontosyllis enopla Verrill, 1900

Odontosyllis enopla Galloway and Welch, 1911, pp. 13–39, 5 pls; Crawshay, 1935, pp. 559–560; Huntsman, 1948, pp. 363–369.

This striking luminescent syllid occurs in the easternmost parts of the Gulf. It is readily distinguished for its dark color, broad nuchal hood that conceals much of the prostomium and its smooth dorsal cirri.

Originally described from Bermuda, this is known to swarm in parts of the West Indies (see citations above).

Haplosyllis spongicola (Grube), 1855

Syllis (Haplosyllis) spongicola Fauvel, 1923, p. 257, fig. 95; Monro, 1933, p. 247.

Haplosyllis spongicola Hartman, 1945, pp. 15–16.

Many finds come from sponge masses attached to piers in Lemon Bay, Florida. In life the color is orange; preserved it fades to flesh-color. Length of body is 10 to 15 mm. for ovigerous individuals. The prostomial and dorsal cirri are neatly articled. Parapodial setae are of a single kind; all are thick, simple, distally bifid, or the main fang may be again divided.

This species is widely recorded from cosmopolitan areas, and is associated with sponges.

Trypanosyllis vittigera Ehlers, 1887

Trypanosyllis vittigera Ehlers, 1887, pp. 151–154, pl. 40, figs. 1–3.

This was taken off southern Florida, collected by A. L. Treadwell. The ventral cirri are unusually prolonged, slender, far surpassing the setigerous lobes throughout the body. The median prostomial antenna is inserted far in front, at the anterior margin of the prostomium; these features agree with those shown by Ehlers (1887, pl. 50).

This species is known only from West Indian seas in addition to southern Florida.

Typosyllis corallicoides Augener, 1922

Syllis (Typosyllis) corallicoides Augener, 1922, pp. 42–43.

This species is known only through its original, non-illustrated account; it was taken at Veracruz, Mexico and at Tortugas, Florida in addition to West Indian localities. Its chief diagnostic features are the presence of alternately long and short dorsal cirri. Length of body is 10 mm. for 81 segments. Antennae and dorsal cirri are articled.

The median antenna has abut 27 articles, the paired ones each about 18. The alternating dorsal cirri have about 29 and 19 articles. The prostomium has 3 pairs of eyes. Setae are composite, have a bifid appendage. Posterior segments have, in addition, single acicular setae. The pharynx and stomach are long, extending to segments 11 and 23 respectively. A pharyngeal tooth is in the second segment.

Ehlersia, sp.

An incomplete specimen comes from Apalachicola, Florida (coll. H. J. Humm). It approaches *Ehlersia cornuta* (Rathke) (see Fauvel, 1923, pp. 267–268, fig. 100) in having some anterior composite setae long-appendaged. The individual is ovigerous, measures 8 mm. long for 40 segments and lacks a part of the tail region. It differs from *E. cornuta* in that the median prostomial antenna is inserted far back at the posterior margin of the prostomium and the palpi are comparatively longer and slenderer. The everted proboscis has 8 soft, blunt, widely spaced lobes and a pale yellow tooth at its middorsum, just behind the circlet of lobes. The prostomium has 3 pairs of eyes of which the middle pair are the largest.

This is the first record of the genus from the Gulf of Mexico.

Synsyllis longigularis Verrill, 1900

Synsyllis longigularis Hartman, 1945, p. 15, pl. 2, fig. 8.

Three specimens come from Franklin Co., Florida (coll. O. Carpenter). Prostomial antennae and dorsal cirri are moniliform; composite hooks of anterior and posterior parapodia are distally bidentate; median segments have simple, Y-shaped setae. The species is elsewhere known from Bermuda and North Carolina (Hartman, 1945).

Autolytus brevicirrata Winternitz, 1936

Autolytus brevicirrata Winternitz, 1936, p. 1, figs. 1–2.

Three specimens come from Franklin Co., Florida (coll. D. Carpenter). Prostomial respects. The single specimen, only 2.5 mm. long is said to have several sexually mature stolons, each about 1.2 mm. long. The other features are too generally shown to distinguish from other species of the genus.

Several species are expected to occur, especially in algal and other frutescent growth in low littoral zones. Free swimming stages of both male (polybostrichus) and female (sacconereis) stages may be taken in plankton during summer months.

Family NEREIDAE

The most ubiquitous and best represented of all annelids in littoral zones of the Gulf of Mexico are species of this family. There are at least 13 species in 7 genera. One is outstandingly euryhaline; others occur in a wide variety of habitats; most are littoral. The chief specific distinction is based on structures of the pharynx. This is often everted or readily observed by a short incision near the midventral line of the peristomium. Its distal end carries a pair of falcate jaw pieces that are toothed along the concave edge. More proximally there are horny or soft papillar structures in specific arrangements. The areas are numbered from I to VIII (pl. 13, figs. 1, 2); areas I

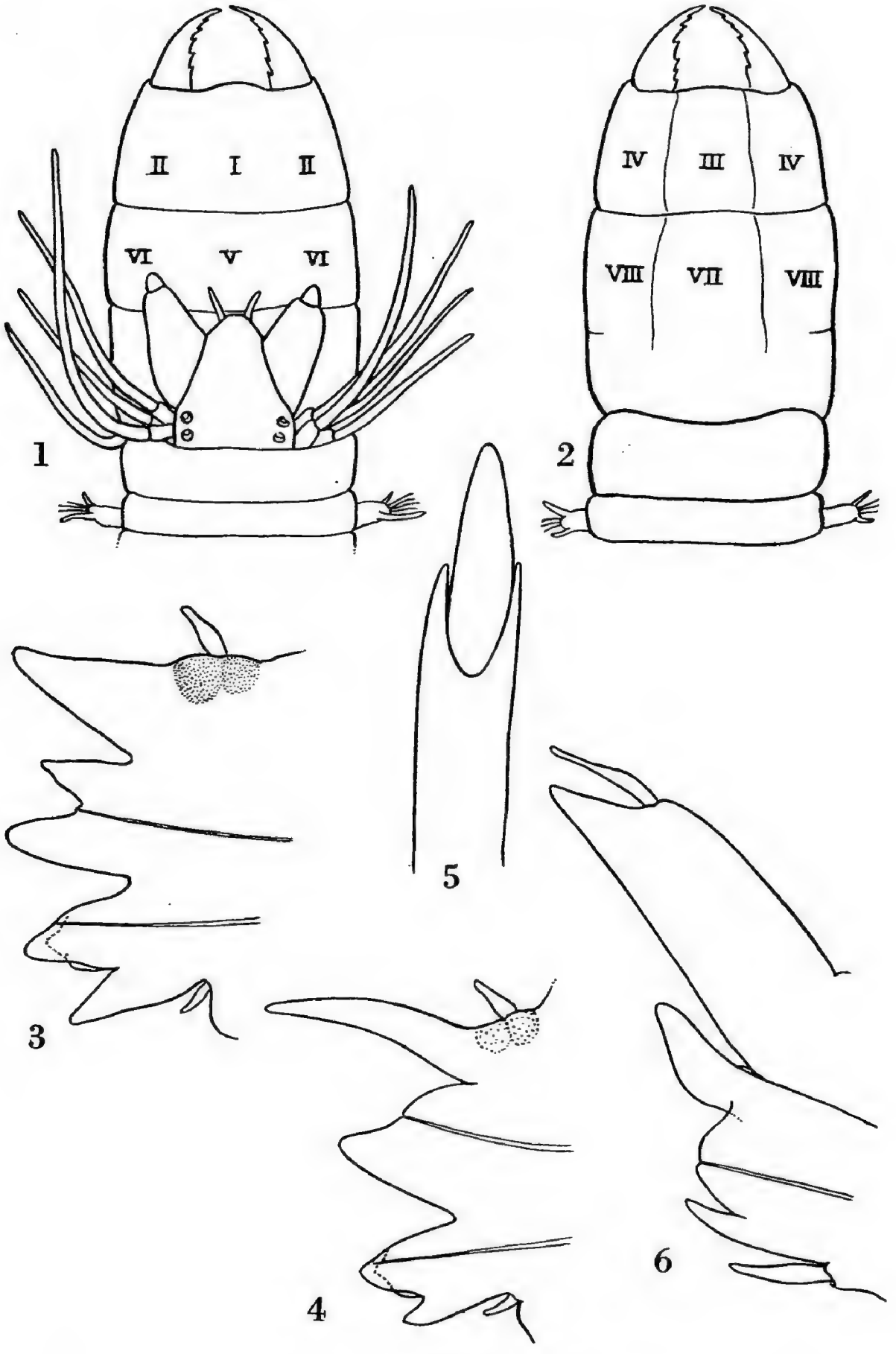


PLATE 13

FIGS. 1 and 2, diagram of the everted proboscis of NEREIDAE, showing order of naming areas on the maxillary ring, I to IV, and oral ring, V to VIII, in dorsal, fig. 1, and ventral, fig. 2, views. (After Moore.)

FIGS. 3 and 4, *Laeonereis culveri* (Webster).

FIG. 3, nineteenth parapodium in anterior view, setae omitted, x 27.

FIG. 4, fortieth parapodium in anterior view, setae omitted, x 27.

FIG. 5, *Nereis largoensis* Treadwell. Distal end of a notopodial homogomph falciger, x 340. (After Treadwell, 1929.)

FIG. 6, *Perinereis anderssoni* Kinberg. A sixteenth last parapodium, setae omitted, x 13.6.

to IV are maxillary, V to VIII are oral; odd numbers are median, even numbers are paired areas.

Key to Species

1. Parapodia lack notosetae, appear uniramous ..... *Lycastopsis tecolutensis*
1. Parapodia with notosetae, clearly biramous 2
2. Pharynx provided with horny paragnaths or these rarely absent; peristomial cirri long to short 3
2. Pharynx provided with horny pectinae or transverse rows of platelets; peristomial cirri greatly prolonged ..... *Platynereis dumerilii*
2. Pharynx provided with only soft papillae in tufts; peristomial cirri very short ..... *Laeonereis culveri*
3. Paragnaths present on both maxillary and oral rings 4
3. Paragnaths present only on maxillary ring, or these also reduced ..... *Ceratonereis* 9
4. Area VI (pl. 13, fig. 1) of proboscis with transverse chitinized bars; peristomial cirri short; dorsum often very dark ..... *Perinereis* 8
4. Area VI of proboscis with cones 5
5. Notopodia with homogomph falcigers (pl. 13, fig. 5) ..... *Nereis* 6
5. Notopodia without homogomph falcigers ..... *Neanthes succinea*
6. Dorsal homogomph falcigers have a short lens-shaped appendage (pl. 13, fig. 5) ..... *Nereis largoensis*
6. Dorsal homogomph falcigers have a longer falcate appendage 7
7. Area VI of proboscis has 4 cones in a cross, areas VII and VIII are continuous and have 2 or 3 rows of cones ..... *Nereis pelagica occidentalis* and *N. oligohalina*
7. Area VI has about 9 minute cones in a heap; areas VII and VIII are continuous and have about 5 larger cones in a single row ..... *Nereis riisei*
8. Posterior notopodial lobes long (pl. 13, fig. 6) ..... *Perinereis anderssoni*
8. Posterior notopodial lobes short ..... *Perinereis floridana*
9. Peristomial cirri short 10
9. Peristomial cirri much longer ..... *Ceratonereis mirabilis*
10. Parapodia have yellow spots; proboscis lacks paragnaths or they are limited to only about 3 cones on area VIII ..... *Ceratonereis tridentata*
10. Parapodia without yellow spots; proboscis with more than 3 paragnaths on the maxillary ring ..... *Ceratonereis irritabilis*

Lycastopsis tecolutlensis Rioja, 1946

Lycastopsis tecolutlensis Rioja, 1946, pp. 211–212, figs. 7–12.

This is reported as estuarine at Tecolutla, eastern Mexico associated with barnacles by Rioja (1946). The genus and species are unique for having uniramous parapodia with the notopodium represented only by an embedded aciculum (see Rioja, 1946, fig. 9). The species is known only from the type locality.

Laeonereis culveri (Webster), 1879

Plate 13, figs. 3, 4

Leptonereis nota Treadwell, 1941, pp. 1–3, figs. 7–10.

Laeonereis culveri Hartman, 1945, p. 21; Behre, 1950, p. 12; Hedgpeth, 1950, p. 111.

This very common, gregarious nereid occurs throughout the Gulf of Mexico in its northern, eastern and western extents, in sandy or muddy sand beaches, at moderately

high to low tidal levels. Specimens from Texas are less than half as large as those from Lemon Bay, Sarasota Co., Florida but similar in other respects.

In life the body may be pink to red, preserved it is pale with a reddish brown mid-dorsal stripe on the anterior third; eyes are dark brown to black or red in juvenile stages. In other individuals the body is bright yellow to greenish in life and pale preserved except for segmental spots over the parapodial bases. Specimens from Florida measure to 60 mm. long, but most are shorter; the posterior end is usually coiled when preserved.

The first 2 parapodia lack notosetae; the dorsal cirrus is small and decreases in size going back where it is far surpassed by the notosetal lobe (figs. 3, 4). The proboscidial areas I to VIII have single tufts of soft filaments with 10 to 15 in a tuft. The jaws are horny yellow. Parapodial acicula are dark. The posterior end of the alimentary tract contains much sand. None of the numerous individuals shows an indication of epitoky; reproduction is probably not effected through heteronereidy.

Laeonereis culveri is the most important burrowing form on the salt flats at Aransas Refuge, Texas and is obviously resistant to periods of low salinity and temporary droughts (Hedgpeth, 1950, p. 111). In some estuaries and sloughs of southwestern Florida it is the only abundant annelid and may occupy extensive muddy flats; its burrows extend perpendicularly in the substratum for a length surpassing that of the animal's length. The species is more widely known from North Carolina south to Brazil and the West Indies.

Neanthes succinea (Frey and Leuckart), 1847

Neanthes succinea Hartman, 1945, pp. 17, 20, 2 figs; Rioja, 1946, pp. 205–206, figs. 1, 2; Hedgpeth, 1950, p. 111; Behre, 1950, p. 12.

This is very abundant in many intertidal areas in the Gulf of Mexico including southwestern Florida to southeastern Texas; it is recorded also from Veracruz, Mexico by Rioja (1946). It occurs commonly among oysters, barnacles, sponges, ascidians, in piling fauna, in sandy mud to very soft mud, under stones or boards, in marine to brackish water.

The characteristic color pattern of the prostomium and the long parapodial lobe of posterior segments clearly distinguish this species from nearly associated ones, especially *Nereis pelagica occidentalis* (see below). Adult individuals become greatly modified to heteronereid stages at sexual maturity; they probably spawn at periodic intervals.

Neanthes succinea is cosmopolitan in distribution, especially in bays and estuaries; it withstands brackish to saline conditions to an unusual degree, and considerable flooding of freshwater. Its geographic range includes temperate to subtropical regions of both hemispheres.

Nereis largoensis Treadwell, 1931

Plate 13, fig. 5

Nereis brevicirrata Treadwell, 1929, pp. 3–5, figs. 9–14.

Nereis largoensis Treadwell, 1931, p. 3.

Nereis gracilicirrata Warren, 1942, pp. 39–40; Behre, 1950, p. 12.

This comes from Key Largo, Florida (Treadwell, 1931) and is further recorded from Grand Isle, Louisiana by Warren (1942) and Behre (1950). It is distinguished from other species of the genus *Nereis* for the presence of a unique composite hook in posterior notopodia; its appendage is lens-shaped and nearly half embedded in the distal end of the shaft (fig. 5, from Treadwell, 1929, fig. 14).

The confusion in specific categories (see synonymies) resulted from the use of a manuscript name, *Nereis gracilicirrata,* which was changed to *N. largoensis* before publication was completed. Furthermore, *N. largoensis* was proposed to replace the preoccupied *N. brevicirrata* Treadwell, 1929, not Treadwell, 1920.

Nereis pelagica occidentalis Hartman, 1945

Nereis pelagica occidentalis Hartman, 1945, p. 20, pl. 4, figs. 1–6; Behre, 1950, p. 12.

Many specimens come from southwestern Florida, among colonies of ascidians, on piles among debris and in empty snail shells. Others are from Louisiana. Four male epitokous individuals come from Corpus Christi, Texas, April 29, 1950 (coll. A. Seamster).

The dorsal notopodial lobes are prolonged much as in *N. largoensis* (see above) but the homogomph falcigers have an appendage that is spinous along one edge (Hartman, 1945, pl. 4, figs. 2, 4). In the male epitokes the first 16 segments have normal parapodia; these are abruptly followed by modified parapodia on 54 segments. There is no third body region. The anal ring is papillated. The 4 eyes are large and have conspicuous circular lenses. These epitokes measure up to 19 mm. long (preserved).

This species is elsewhere known from North Carolina.

Nereis oligohalina (Rioja), 1946

Neanthes oligohalina Rioja, 1946, pp. 207–210, pl. 1, figs. 4–6, pl. 2, figs. 13–19.

This is recorded from Veracruz and in esteros of Tecolutla, Mexico from between shells of *Mytilus.* I am here referring the species to *Nereis* since posterior notopodia are provided with homogomph falcigers (see Rioja, 1946, pl. 1, fig. 5). The species appears to be inseparable from *Nereis pelagica occidentalis* (see above).

Nereis riisei Grube, 1856

Nereis riisei Augener, 1922, p. 42; Monro, 1933, p. 256.

This is recorded from Veracruz, Mexico and Florida Keys by Augener (1922). Three specimens come also from Thornton Island, Sarasota Co., Florida from a rocky reef.

The proboscis is unique for having areas VII and VIII provided with a single row of 5 larger paragnaths; area V is bare and VI has about 9 minute cones in a heap. These parts are shown by Hoagland (1919, pl. 30, figs. 1–6) for *Nereis glandulata,* a synonym of *Nereis riisei* Grube.

This occurs on both sides of temperate and tropical America but is not yet known from the northern part of the Gulf of Mexico.

Platynereis dumerilii (Audouin and M. Edwards), 1833

Platynereis dumerilii Fauvel, 1923, pp. 359–360, fig. 141; Monro, 1933, p. 257; Rioja, 1950, p. 75; Behre, 1950, p. 12.

Uncinereis trimaculosa Treadwell, 1940, p. 3, figs. 4–9.

Several finds are from western Florida and Texas. Others are from between Rockport and St. Joseph Island, Texas, 2 miles off shore, October, 1950 (coll. A. E. Hartman). It is reported also from Louisiana by Behre (1950) and eastern Mexico by Rioja (1950). It is associated with algal fronds such as *Sargassum.*

Individuals from Texas are small, measuring only about 20 mm. long. In some the pigmented patches of parapodia on the dorsal side are very intense, in others they are pale or perhaps faded.

P. dumerilii has a wide geographic distribution in warm seas and is most commonly found in algal masses.

Perinereis anderssoni Kinberg, 1866

Plate 13, fig. 6

Nereis bairdii Webster, 1884, pp. 312–313, pl. 8, figs. 22–28.

Perinereis anderssoni Hartman, 1948, pp. 72–73 (with synonymy).

This occurs in the eastern part of the Gulf of Mexico. It is readily identified for having posterior notopodial lobes much prolonged (fig. 6); area VI of the proboscis has transverse ridges as characteristic of the genus *Perinereis.*

P. anderssoni is common in West Indian localities, also Bermuda and south to Brazil; it is not yet known from the western half of the Gulf of Mexico.

Perinereis floridana (Ehlers), 1864–68

Nereis floridana Ehlers, 1864–68, pp. 503–506.

Perinereis floridana Monro, 1933, p. 256.

Four individuals come from Lemon Bay, Sarasota Co., Florida washed from debris taken from a sandy shoal. Three of them are male epitokes near the swarming stage, the other is an atokous one posteriorly not quite complete. The epitokes measure about 35 mm. long, the other nearly 45 mm. long.

The posterior parapodial lobes are short, resembling those of median segments and are thus not to be confused with those of *P. anderssoni* (see above). On the proboscis the maxillary ring has the following parts: area I has 2 small cones in tandem, II has 3–4 in a heap, III has 6 cones in 2 transverse rows, and IV has about 10 cones in a heap on each side. On the oral ring area V has 3 cones in a nearly transverse line, VI has on each side a single larger transverse ridge or 2 smaller ones that are closely set, VII and VIII are continuous and have about 21 cones in 3 irregular rows. The pieces on areas VII and VIII are slightly the largest of the cones. In the male epitokes there are 16 anterior segments abruptly followed by the natatory segments which number about 80; there is no unmodified posterior region; the anal ring is papillated.

Perinereis floridana is known only from the vicinity of the Florida Keys and northward to Sarasota County, Florida.

Ceratonereis irritabilis (Webster), 1879

Nereis irritabilis Webster, 1879, pp. 231–234, figs. 56–69.

Ceratonereis irritabilis Hartman, 1945, pp. 20–21, pl. 3, figs. 7–9; Behre, 1950, p. 12.

Two lots come from Grand Isle, Louisiana from mud and sand. Color in life is light gray changing to bluish in median segments; parapodial bases are green and the posterior part of the body is brass colored. In epitokous males the parapodial change is at the thirty-fourth segment. On the proboscis the paragnaths are present on all areas of the maxillary ring except I where they are absent.

This is more widely known from Virginia and North Carolina.

Ceratonereis tridentata (Webster), 1879

Nereis tridentata Webster, 1879, pp. 113–115; Webster, 1886, pp. 142–143, pl. 7, figs. 33–40.

Ceratonereis tridentata Hartman, 1945, p. 21, pl. 3, figs. 3, 4.

Specimens come from Pass Christian, Mississippi, Feb., 1946 (coll. J. and W. Rapp, Jr.) and off Port Isabel, Texas Nov. 1947 (coll. J. W. Hedgpeth). This species bears a striking superficial resemblance to *Laeonereis culveri* (see above) in having very short peristomial cirri. Also, it typically occurs at a lower tidal level and is associated with a shelly bottom. The body is long and slender. On the proboscis paragnaths are nearly lacking, with at most about 3 small paragnaths on area VII (hence the specific name). The species is clearly separable from *Laeonereis culveri* in that its posterior parapodia have well developed dorsal cirri and lobes.

The species is known otherwise from New Jersey and North Carolina.

Ceratonereis mirabilis Kinberg, 1866

Nereis gracilis Webster, 1884, pp. 313–314, pl. 9, figs. 29–35.

Ceratonereis tentaculata Monro, 1933, p. 256.

Ceratonereis mirabilis Hartman, pp. 71–72.

Three individuals come from Thornton Island, Sarasota Co., Florida associated with littoral algae, Jan. 1938. The species is clearly characterized for having greatly prolonged peristomial cirri and widely spreading palpal bases (see Webster, 1884, pl. 9, fig. 29). The proboscis has cones only on the maxillary ring where they are numerous and occur on all areas.

C. mirabilis is a tropical species and widely known from both sides of the Western Hemisphere in addition to extra-American localities. It is not yet known from the western part of the Gulf of Mexico.

Family NEPHTYIDAE

The nephtyids are sometimes called sand-worms because their occurrence is almost completely limited to sandy beaches. In life they are usually pearl to slate gray or a darker pigmented pattern may be present in anterior dorsal parts. The species are errantiate, burrow in shifting sands or mud and may be sufficiently abundant to form

beds. The proboscis is an eversible compressed cylinder distally provided with prolonged papillae; a pair of jaws is present, some distance within the inner cylinder but seen only by dissection. Two closely related species are recorded.

Key to Species

1. Dorsum of body pale ..... *Nephtys bucera*
1. Dorsum considerably pigmented dark or brown ..... *Nephtys picta*

Nephtys picta Ehlers, 1864–68

Plate 10, fig. 4

Nephthys picta Ehlers, 1864–68, pp. 632–635, pl. 23, figs. 9, 33.

Nephtys picta Hartman, 1945, pp. 22–23; Hartman, 1950, pp. 103–105; Behre, 1950, p. 12.

Several individuals come from southern and northwestern Florida; others are from Horn Island, Mississippi and from Grand Isle, Louisiana. The largest ones measure 80 mm. long. The dorsum is dusky with pigmented bars which may fade on preservation. Branchiae are first present from the fourth segment. The postacicular setae, in the middle of the fascicle of both notopodia and neuropodia have 4 to 6 coarse spinous processes that increase in size distally (fig. 4); this character is visible even under low magnification.

N. picta is more extensively recorded from New England and southward into the Gulf of Mexico (Hartman, 1950).

Nephtys bucera Ehlers, 1864–68

Nephthys bucera Ehlers, 1864–68, pp. 617–619, pl. 23, fig. 8.

Nephtys bucera Hartman, 1950, pp. 105–106.

Specimens which I regard as this species come from Alligator Harbor, northwestern Florida. Branchiae are present from the fourth, or not until the fifth segment; the dorsum is pale, not pigmented. In other respects they agree with *N. picta* (above). The postacicular setae are similarly coarsely serrated (see pl. 10, fig. 4) along a basal portion. When these spines are sloughed off or worn away the setae have a different appearance and give the impression of belonging to another species. The distinction between *N. bucera* and *N. picta* is slight but may be defended on the basis of color pattern and possibly representing ecological forms.

N. bucera is more widely known from New England southward into the Gulf of Mexico.

Family GLYCERIDAE

The glycerids or proboscis worms occur in sandy or muddy habitats in littoral seas. They are active burrowers, have a prolonged conical anteriorly tapering prostomium that is transversely annulated and ends in front in 4 minute antennae arranged in a cross. The proboscis is long, cylindrical or distally widest, eversible for a considerable length; at its distal end it has a circlet of soft papillae and 4 sets of dark corneous jaw pieces. Two species are recorded.

Key to Species

1. Branchial processes eversible as palmately branched lobes from the posterior side of parapodia ..... *Glycera americana*
1. Branchial lobes not eversible, consist of single digitate lobes at upper and lower ends of parapodia ..... *Glycera dibranchiata*

Glycera americana Leidy, 1855

Glycera americana Leidy, 1855, pp. 147–148, pl. 11, figs. 49, 50; Warren, 1942, pp. 42–43; Hartman, 1945, p. 23; Rioja, 1946, p. 194; Behre, 1950, p. 12.

This comes from Lemon Bay, Florida in sandy beaches, from Grand Isle, Louisiana in oyster beds, June, 1942 (coll. J. H. Roberts), from Wakulla Beach and Alligator Harbor in northwestern Florida, Jan. and May, 1950 (coll. L. M. Henry) and is reported from Louisiana by Warren (1942) and Behre (1950); also from Tecolutla, Mexico by Rioja (1946).

Individuals come to be large, attain a length of 50 to 100 mm. or more. Median and posterior parapodia have conspicuous eversible branchiae that are retractile from a pore on the posterior face of neuropodia. Color in life is purplish red fading to red or pink; preserved it is flesh colored or somewhat brownish.

This is elsewhere known from both sides of America, in temperate to warm seas, in littoral and shallow dredged depths; it is further known from widely scattered localities in the Pacific Ocean. It has some economic value as fish bait (see Sandrof, 1946, pp. 775–786).

Glycera dibranchiata Ehlers, 1864–68

Glycera dibranchiata Ehlers, 1864–68, pp. 670–702, pl. 24, figs. 3–8, 10–28; Hartman, 1945, p. 23.

Four finds come from Port Aransas, Texas, near the docks of the Institute of Marine Science, Jan. 1950 (coll. C. A. Schultz).

The longest (preserved) measures 49 mm. long, 2.5 mm. wide without and 3.3 mm. wide with parapodia. The anterior end, behind the slender, conical proboscis, is enlarged and tapers rapidly farther back. The branchial processes on upper and lower parapodial parts readily distinguish this species. It is known to occur from the New England states south to North Carolina, also from southern California, western Mexico and into the Caribbean Sea.

Superfamily EUNICEA

The next 6 families comprising the ONUPHIDAE, EUNICIDAE, LUMBRINERIDAE, ARABELLIDAE, LYSARETIDAE and DORVILLEIDAE are conveniently grouped as a superfamily since they have a characteristic pharyngeal apparatus. The body may be plain (LUMBRINERIDAE) to variously ornamented with fleshy structures (some ONUPHIDAE); it may be minute or only a few mm. long as in some DORVILLEIDAE or it may be several cm. long. The paragnaths consist of simple paired ventral plates called mandibles (pl. 15, fig. 3) and paired or unpaired dorsal plates called maxillae (pl. 14, fig. 3). The latter are again recognized for having a pair of basal plates or carriers, a pair of strongly falcate pieces or forceps, called maxillae I, and successive toothed platelets numbered from II to IV, V or many, in

more distal arrangement. These paragnathal parts have specific significance and very clearly distinguish the families from one another.

Key to Families of EUNICEA

1. Prostomium a plain semicircular or conical lobe (pl. 16, fig. 1) lacking processes or these limited to 3 minute antennae at the postmedian margin (pl. 14, fig. 7) 2
1. Prostomium with more conspicuous processes or antennae 4
2. Prostomium with 3 minute antennae at postmedian margin ..... LYSARETIDAE
2. Prostomium lacks antennae 3
3. Parapodia with hooded hooks (pl. 15, fig. 4); maxillary carriers short ..... LUMBRINERIDAE
3. Parapodia without hooded hooks; maxillary carriers long (pl. 16, fig. 4) ..... ARABELLIDAE
4. Prostomial antennae conspicuously ringed at base (pl. 14, fig. 1) .... ONUPHIDAE
4. Prostomial antennae not ringed at the base 5
5. Prostomium with a median antenna; body larger ..... EUNICIDAE
5. Prostomium without a median antenna; body smaller, sometimes minute ..... DORVILLEIDAE

Family ONUPHIDAE

The prostomium has 5 long tentacular processes in which the basal article is ringed (pl. 14, fig. 1); frontal prostomial antennae are paired and much smaller by comparison. Four species are recorded.

Key to Species

1. Branchiae spiralled ..... *Diopatra cuprea*
1. Branchiae not spiralled 2
2. Branchiae first present from first segment; ventral cirri cirriform through 6 segments, thereafter padlike; prostomium with a pair of eyespots (pl. 14, fig. 1) ..... *Onuphis eremita oculata*
2. Branchiae first present from about the sixth segment; ventral cirri cirriform through 5 segments; prostomium without eyespots ..... *Onuphis magna*
2. Branchiae first present behind the twentieth segment; tube long, quill-like, not attached ..... *Hyalinoecia tubicola*

Diopatra cuprea (Bosc), 1802

Plate 3, bottom

Diopatra spiribranchis Augener, 1906, pp. 145–148, pl. 5, figs. 88–96.

Diopatra cuprea Warren, 1942, p. 44; Hartman, 1944, p. 54, pl. 1, figs. 9–14; Hartman, 1945; p. 26; Behre, 1950, p. 12.

Many collections come from intertidal beaches throughout the Gulf of Mexico in its northern and western ends. The coarse tubes occur in hard packed sand or detritus strewn beaches at Bald Point, Florida, at Padre Island, Texas, at and near Grand Isle, Louisiana and in southwestern Florida. According to Dr. Laura Henry (in litt.) in the spring of 1950, "at Bald Point the number of *Diopatra* tubes in a square yard at low tide line varied from 65 to 93. In higher areas the numbers were from 29 to 47." The broken tubes may be washed up in great number after storms (pl. 3).

This species provides suitable material for laboratory culture since the long egg strings can be taken into the laboratory and retained at ordinary temperatures. Adults can be kept and observed at tube-building, as described by Linville (1903). Regeneration studies are possible since specimens deprived of the anterior end replace them within a relatively short time.

This species is widely recorded from parts of the western Atlantic, including New England south to Brazil; it appears to be common in littoral zones of the Gulf of Mexico.

Hyalinoecia tubicola (Müller), 1788

Hyalinoecia tubicola Fauvel, 1923, pp. 421–422, fig. 166.

Many large tubes, to 13 inches long, were trawled south of Pensacola, Florida in 305 fms. from a bottom of stringy blue-gray mud by the M/V OREGON in Feb. 1950 at station 279.

The species is known from cosmopolitan seas in abyssal depths.

Onuphis magna (Andrews), 1891

Diopatra magna Andrews, 1891, p. 21, pl. 2, figs. 1–7; Andrews, 1891, pp. 286–287, pl. 14, figs. 14–20.

Onuphis magna Monro, 1933, p. 257; Hartman, 1945, p. 26.

This comes from southwestern Florida in sandy mud beaches. In its habitats it resembles *Diopatra cuprea* (above) but occurs in finer sand or mud. The tube is long, cylindrical, erect in the substratum; in its size it may surpass that of *Diopatra cuprea* (Bosc). Parapodial branchiae are first present at about the sixth segment and come to be pectinately divided farther back, with up to 6–12 filaments at greatest development.

In life the body is dark but the first few segments are flesh color with diffusely scattered minute dark specks. In the middle the body is olive green to brown and branchiae are dark red to brown.

This is known from North Carolina, through the West Indies, southern Florida, Pacific side of tropical America; it is not yet recorded from the western part of the Gulf of Mexico.

Onuphis eremita oculata, new subspecies

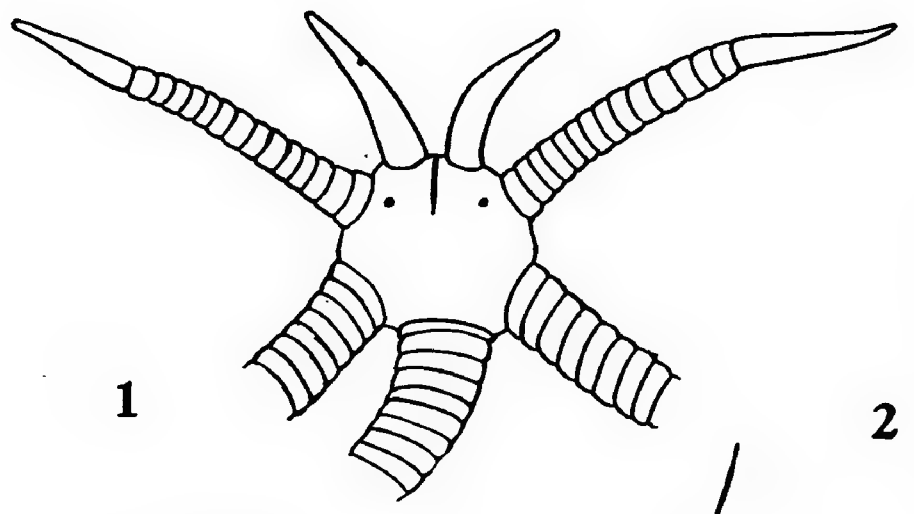
Plate 14, figs. 1, 2

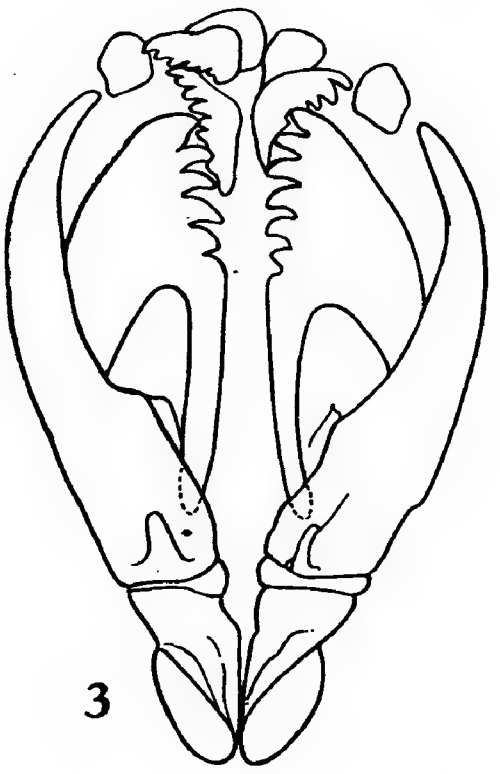
Onuphis eremita Audouin and M. Edwards, 1834 (stem species); Behre, 1950, p. 12.

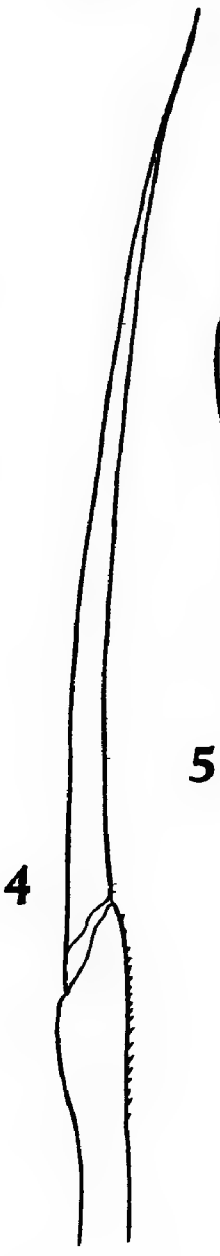
Collections come from Alligator Point and Bald Point in southwestern Florida, from Grand Isle, Louisiana, from Port Aransas, Texas, and near the dock of the Institute of Marine Science, Port Aransas (coll. C. A. Schultz).

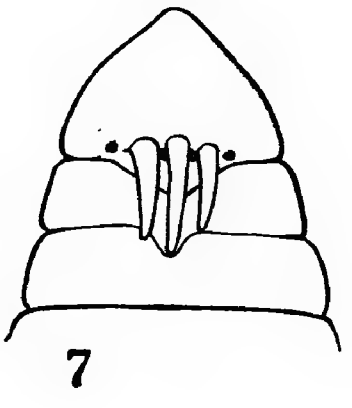
The body comes to be long and slender; a complete specimen may have 250 segments or more and attain a length of 56 mm. and width of 1.5 mm. Others are smaller.

There is little color (preserved) except for a few reddish brown spots or dashes in segmental arrangement. There are spots at the bases of the antennae and ceratophores









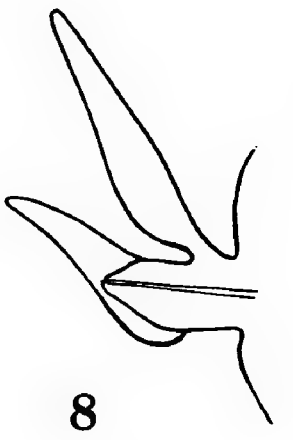


PLATE 14

FIGS. 1, 2, *Onuphis eremita oculata*, n. subsp.
FIG. 1, prostomium in dorsal view, x 56.
FIG. 2, distal end of tridentate hook from second segment, enlarged.
FIGS. 3 to 6, *Marphysa sanguinea* (Montagu). (After Moore.)
FIG. 3, maxillae in dorsal view, x 14.
FIG. 4, distal end of composite seta, x 248.
FIG. 5, distal end of a pectinate seta, x 248.
FIG. 6, distal end of a subacicular seta, x 248.
FIGS. 7, 8, *Lysarete brasiliensis* Kinberg.
FIG. 7, anterior end in dorsal view, x 20.
FIG. 8, a median parapodium in anterior view, x 10.5.

as also at the sides of the body, above and behind the parapodial bases; broken bars cross the posterior margin of the peristomium and similar bars may occur on a few of the anterior segments in front of the segmental grooves. Otherwise the body is pale.

The prostomium has a pair of small, circular eyespots at its anterior end located within the bases of the outer lateral ceratophores and behind the frontal antennae (fig. 1); there is a shallow median sulcus.

Branchiae are present from the first setiger with single filaments and continued so through about 20 segments; thereafter there are 2 filaments for 4 to 5 or 8 segments and 3 to 6 filaments in pectinate arrangement through a long region extending to or beyond the posterior third of the body. The number of filaments again diminishes thereafter to 2 and gradually single processes so that they are little more than small knobs at the posterior end.

Dorsal cirri are large from the first, surpassing the size of any of the branchial filaments; they remain much the same throughout the body. Ventral cirri are cirriform through the first 6 setigers and abruptly padlike thereafter.

Segments 5 to 9 have a small conical lobe between the dorsal cirrus and the setigerous lobe; its form is similar to that of the presetal lobe but somewhat smaller; it disappears abruptly thereafter.

The body terminates in 4 long, cirriform, subequal cirri that are attached so that 2 are dorsal and 2 ventral, with no space between their bases; their length is about 12 times their width at the base. The first few segments have composite falcigers that are distally tridentate, with the distal tooth largest and falcate, and the most proximal tooth the smallest; the denticles are about at right angles to the shaft (fig. 2). There is variation in the degree of development of the most proximal tooth to a mere vestige, but it is this and not the median tooth that varies in size.

The maxillary formula, based on a larger individual is as follows: the forceps or I is a falcate piece, II has 8 teeth on the left side and 9 on the right, III has 9 on the left side and none on the right, IV has 6 on the left side, 11 on the right side, V is a large dark piece on either side.

The tube is long, with a thin membranous lining and a layer of fine sand without; it is limp and collapsed when the individual is removed; it measures at least 90 mm. long but is easily torn and may thus be incomplete.

The subspecies, *oculata* differs from the stem species, *O. eremita* Audouin and M. Edwards most conspicuously for having eyes instead of lacking them; anal cirri consist of 4 subequal processes instead of 2 longer dorsal and 2 shorter ventral ones; the anterior tridentate falcigers differ (see Fauvel, 1923, p. 416, fig. 164, for details). *Onuphis eremita parva* Berkeley and Berkeley (1941, pp. 35–36) from southern California is also an oculate variety of the same species. It is much smaller, attaining a length of only 18 mm. for 54 segments when sexually mature. The branchiae attain to 4 or 5 filaments where best developed.

The holotype specimen is selected from Franklin County, Florida. More extensive distribution includes other intertidal sands of the Gulf of Mexico, west to Texas.

Family EUNICIDAE

The eunicids differ from the onuphids (above) by lacking the ringed bases of prostomial appendages; the prostomium lacks the small paired antennae and the maxillary jaw pieces (pl. 14, fig. 3) typically have fewer teeth. Ten species are reported.

Key to Species

1. Peristomial ring with dorsal cirri 2
1. Peristomial ring without cirri ..... *Marphysa* 9
2. Prostomium with 5 antennae, in adult stage 3
2. Prostomium with 3 antennae ..... *Lysidice ninetta*
3. Prostomial antennae short and smooth; branchial filaments absent through a long region of 50–60 segments; mandible much larger than maxillae ..... *Palola siciliensis*
3. Prostomial antennae smooth or articled; branchial filaments usually present on anterior segments; mandible not so enlarged 4
4. Branchial filaments somewhat to much divided ..... *Eunice (Eunice)* 5
4. Branchial filaments simple and undivided where present ..... *Eunice (Nicidion) kinbergi*
5. Prostomial antennae moniliform or articled ..... *Eunice rubra*
5. Prostomial antennae smooth or somewhat wrinkled but not articled 6
6. Branchiae few, absent from a long anterior region ..... *Eunice filamentosa*
6. Branchiae well developed, present in anterior segments 7
7. Branchiae with 6 or more filaments where best developed 8
7. Branchiae with only 3 or 4 filaments at maximum development ..... *Eunice mutilata*
8. Subacicular hooks distally bifid ..... *Eunice floridana*
8. Subacicular hooks distally entire ..... *Eunice schemacephala*
9. Composite setae distally pointed (pl. 14, fig. 4.) ..... *Marphysa sanguinea*
9. Composite setae distally hooked and bifid ..... *Marphysa regalis*

Eunice rubra Grube, 1856

Eunice ornata Andrews, 1891, pp. 284–285, pl. 13, figs. 6–13.

Eunice rubra Monro, 1933, p. 257; Hartman, 1945, p. 24.

A find comes from Dry Tortugas, Florida associated with reefs (coll. A. L. Treadwell). The prostomial antennae are long, distinctly articled. Branchiae are present from about the fifth segment, continued through a long region and have pectinately arranged filaments where best developed. Acicular hooks and setae are yellow; subacicular hooks are distally tridentate. These features are well illustrated by Andrews (1891, pl. 13).

This is common along rocky coasts of southeastern United States and southern Florida, in sponge, bryozoan and other attached growths. It is more widely recorded from both sides of America in warm seas, but has not yet been recorded from the western half of the Gulf of Mexico.

Eunice mutilata Webster, 1884

Eunice mutilata Webster, 1884, pp. 315–316, pl. 9 figs. 36–40; Monro, 1933, p. 257; Hartman, 1944, pp. 113–114, figs. 140, 141.

One comes from Dry Tortugas, Florida (coll. A. L. Treadwell). The dorsum is marked with a reticulated or finely checkered pattern and the entire dorsum is speckled with dark spots. Prostomial antennae are short, smooth or somewhat wrinkled. Branchiae are first present from segment 6–9, continued through a long region and come to have 5–10 filaments where best developed. Acicular hooks are distally bifid, embedded acicula are dark to black.

This occurs on both sides of America in warm seas (Hartman, 1944); it is not yet known from the western part of the Gulf of Mexico.

Eunice filamentosa Grube, 1856

Eunice denticulata Webster, 1884, pp. 316–317, pl. 10, figs. 41–45.

Eunice filamentosa Hartman, 1944, p. 107, figs. 123–126.

A find comes from Dry Tortugas, Florida (coll. A. L. Treadwell). The prostomial antennae are short, smooth or somewhat wrinkled. The peristomium is somewhat longitudinally wrinkled. Branchiae are absent from a long anterior region; they arise as simple filaments on the anterior third of the body and come to have few filaments at maximum development. The heavy subacicular hooks are strongly beaked; acicula are dark to black.

This is widely known from tropical eastern and western America including Bermuda and southern Florida; it is not yet known from the northern or western ends of the Gulf of Mexico.

Eunice schemacephala Schmarda, 1861

Eunice fucata Ehlers, 1887, pp. 91–93, pl. 25. figs. 8–20.

Leodice fucata Warren, 1942, p. 45.

Eunice schemacephala Hartman, 1944, p. 121.

This comes from Dry Tortugas, Florida (coll. A. L. Treadwell) and is recorded from Grand Isle, Louisiana by Warren (1942). It is associated with reefs. Prostomial antennae and peristomial cirri are smooth. Branchiae are present from about the fifth segment and come to have many filaments in pectinate arrangement; they are continued back through a long region. Acicula are dark to black.

This eunicid has swarming habits similar to those of the South Pacific palolo, *Palola viridis* Gray. It is sometimes called the Atlantic palolo worm. Its annual periodic appearance in the plankton takes place in July (see Clark and Hess, 1940, pp. 23–70). The species has not yet been recorded from the western end of the Gulf of Mexico.

Eunice floridana (Pourtalés), 1869

Eunice floridana Ehlers, 1887, pp. 88–90, pl. 22, figs. 1–7.

One large and several smaller individuals were taken from a living shell of the gastropod, *Tugurium (Trochotugurium) longleyi* Bartsch off southwestern Florida, 24° 21′ N., 82° 42′ W. in 117 fms., Jan. 21, 1951, by the M/V OREGON, station 243. The largest specimen completely filled the umbilical chamber of the shell; the tail end of the tube was in the uppermost spiral and the head end extended some distance below the shell. Numerous smaller individuals of varying sizes occupied crevices or runways in other parts of the shell; there was never more than one worm within a single tube.

The parchment-like tube has the chalky white appearance of a serpulid tube; it is flexible, however, and lacks the rigid firmness and thickness of calcareous tubes. Its head end is more or less broadly flaring and its lateral walls have the false openings which are shown by Ehlers (1887, pl. 22).

Prostomial antennae extend forward beyond the prostomium and are smooth except for wrinkles of contraction. Branchial filaments are well developed and are occasionally secondarily divided.

The species is more widely known from the West Indies and deep water of eastern United States in depths to 399 fms.

Eunice (Nicidion) kinbergi Webster, 1884

Nicidion kinbergi Webster, 1884, pp. 320–321, pl. 12, figs. 81–88.

Eunice cariboa kinbergi Monro, 1933, p. 257.

Eunice (Nicidion) kinbergi Hartman, 1944, p. 124 (with synonymy).

This comes from Dry Tortugas, Florida (coll. A. L. Treadwell). It differs sharply from other species of *Eunice* in that branchiae are totally lacking; its prostomial antennae are smooth.

It is known more extensively from the West Indies south to Panama and north to Bermuda, associated with reefs. It is not yet known from the western part of the Gulf of Mexico.

Marphysa sanguinea (Montagu), 1815

Plate 14, figs. 3–6

Marphysa aransensis Treadwell, 1939, p. 5, figs. 16, 17.

Marphysa sanguinea Hartman, 1944, pp. 126–128, pl. 8, figs. 179–183; Hartman, 1945, pp. 23–24; Behre, 1950, p. 12.

Many specimens come from various parts of the Gulf of Mexico including Florida to Texas, from clay and muddy banks that may be mixed with sand, and from oyster beds. The species grossly resembles that of a *Eunice* but peristomial cirri are absent. The 5 prostomial antennae are short and smooth. Branchiae are first present at the tenth or a later segment and come to have 4 to 6 filaments in pectinate arrangement where best developed. Composite setae are distally pointed (fig. 4); posterior segments have large, comb-like setae with several teeth (fig. 5). Subacicular hooks are distally bifid (fig. 6).

This is cosmopolitan in warm seas and littoral; it sometimes occurs abundantly and may be an important source of food for larger animals.

Marphysa regalis Verrill, 1900

Marphysa regalis Treadwell, 1921, pp. 66–69, pl. 5, figs. 9–12, text figs. 224–235.

One comes from Loggerhead Key, Florida from soft friable rock (coll. A. L. Treadwell). The species is readily separable from *M. sanguinea* (above) for having composite setae that have an appendage which is distally hooked and bifid.

This is otherwise known from the West Indies and Bermuda in reefs. It is not yet known from the western part of the Gulf of Mexico.

Palola siciliensis (Grube), 1840

Eunice siciliensis Fauvel, 1923, pp. 405–407, fig. 159.

Palola siciliensis Hartman, 1944, p. 131; Rioja, 1946, p. 194.

This comes from Dry Tortugas, Florida (coll. A. L. Treadwell) and is recorded from Veracruz, Mexico by Rioja (1946). Individuals occupy galleries in calcareous

rocks. The 5 prostomial antennae and 2 peristomial cirri are short and smooth. Mandibles are large, their calcareous plates usually seen projecting from the oral cavity. Branchiae are inconspicuous, absent from a long anterior region and have only single filaments where developed.

This is a cosmopolitan, widely distributed, warm water species, known from both hemispheres. It has not yet been taken in the environs of the Mississippi delta.

Lysidice ninetta Audouin and M. Edwards, 1833

Lysidice ninetta Fauvel, 1923, pp. 411–413, fig. 162; Rioja, 1946, p. 194.

This is recorded from Veracruz, Mexico by Rioja (1946). The species can be identified for having only 3 prostomial antennae when adult; the prostomium is clearly bifid in front and peristomial cirri as well as branchiae are absent.

This is cosmopolitan in warm seas, associated with calcareous rocks and shells in littoral zones.

Family LUMBRINERIDAE

The lumbrinerids resemble the arabellids (below) in having a plain, cylindrical body and simple prostomium. Five species are recorded.

Key to Species

1. Some parapodia have branched branchial processes (pl. 16, fig. 2) ..... *Ninoë nigripes gracilis*
1. Parapodia without branched branchiae 2
2. Composite hooks present in some anterior segments ..... *Lumbrineris inflata*
2. Composite hooks absent 3
3. Median segments with a wing-like membrane (pl. 15, fig. 1) at posteroventral position ..... *Lumbrineris alata*
3. Wing-like membrane absent 4
4. Posterior postsetal lobes prolonged and more or less erect ..... *Lumbrineris bassi*
4. Posterior postsetal lobes short throughout ..... *Lumbrineris parvapedata*

Lumbrineris bassi Hartman, 1944

Lumbrineris bassi Hartman, 1944, pp. 150–151, figs. 217–223; Behre, 1950, p. 12.

This comes from Sarasota Co., Florida in sand bars and from sand filled snail shells, also from Barataria beach, Grand Isle, Louisiana.

The body is very long and slender, resembling that of a drilonereid (below); it measures to 50 mm. long and is less than 2 mm. wide. Setae in the first 15 segments are entirely pointed. Simple hooded hooks are present thereafter and gradually replaced the pointed setae in posterior segments. Acicula are yellow. In far posterior segments the postsetal lobe comes to be long and erect.

This is known from southwestern Florida and Louisiana, in sandy shoals.

Lumbrineris parvapedata (Treadwell), 1901

Lumbriconereis parvapedata Treadwell, 1901, p. 198, figs. 38–40.

Lumbrinereis elongata Treadwell, 1931, p. 3, fig. 3; Warren, 1942, p. 45.

Lumbrineris parvapedata Hartman, 1942, pp. 118–119, fig. 10; Hartman, 1944, p. 144; Behre, 1950, p. 12.

Three lots come from Grand Isle, Louisiana and vicinity, from sandy beaches. This species is very long, cylindrical, with parapodia that are unusually inconspicuous. The anterior middorsum has a longitudinal dark stripe (persisting in preservative). Anterior parapodia have simple hooded hooks accompanying the simple setae. Posterior parapodia lack the pointed setae and have only a few hooks in a fascicle. Embedded acicula are yellow. Throughout the body the postsetal lobe is slightly longer than the presetal one but it is never slender or prolonged.

This occurs elsewhere from Culebra and the Atlantic side of Panama, based on Treadwell's original records (1901).

Lumbrineris inflata (Moore), 1911

Lumbrineris inflata Hartman, 1944, pp. 160–161.

This is reported from the eastern end of the Gulf of Mexico by Hartman (1944); two others are from Alligator Harbor, Franklin Co., Florida, March, 1951 (coll. D. Carpenter). The species is characterized for having composite hooded hooks in anterior segments; the posterior postsetal lobe is prolonged. Each of the maxillary plates, pairs III and IV, have several teeth.

Originally described from southern California, this is known from both sides of America in warm, littoral seas.

Lumbrineris alata, new species

Plate 15, figs. 1–4

Collections come from various parts of the Gulf of Mexico, from Florida to Texas. A posterior fragment comes from Grand Terre, near Grand Isle, Louisiana, front beach, July, 1942 (coll. J. H. Roberts), another from Peninsula Point, Franklin Co., Florida, August, 1950 (coll. H. J. Humm) and several large ones are from a slough near the jetty adjacent to the Institute of Marine Science, Port Aransas, Texas, under a foot of water buried 6–8 inches in silt October, 1950 (coll. A. E. Hartman); two others are from Mustang Island, Texas, July, 1946 (coll. J. W. Hedgpeth).

In life the body is bright to deep red. The largest ones measure 150 mm. long for over 300 segments and up to 4 mm. wide. Another smaller, posteriorly incomplete one from Mustang Island measures 62 mm. long for 157 segments. The prostomium is broadly rounded in front; eyes are lacking. From the first, parapodia have simple setae and 1 or 2 simple hooded hooks; in posterior segments the pointed setae come to be entirely replaced by hooded hooks (fig. 4). Embedded acicula are yellow.

Mandibles and maxillae (figs. 2–3) are present with characteristic parts. The mandibles are completely fused along their midlength and more than twice as long as wide. Maxillae have carriers that are unique for being broad at their upper end (fig. 2). Forceps have single points, II has 5 (rarely 4) teeth on a side, III has 2 teeth on a side and IV has a single long point on a side.

In all parapodia the postsetal lobe is longer than the presetal one. In median segments the hinder lobe elongates and comes to stand erect (fig. 1). A unique and seemingly specific feature is the presence of fleshy lobes (fig. 1) at the postventral

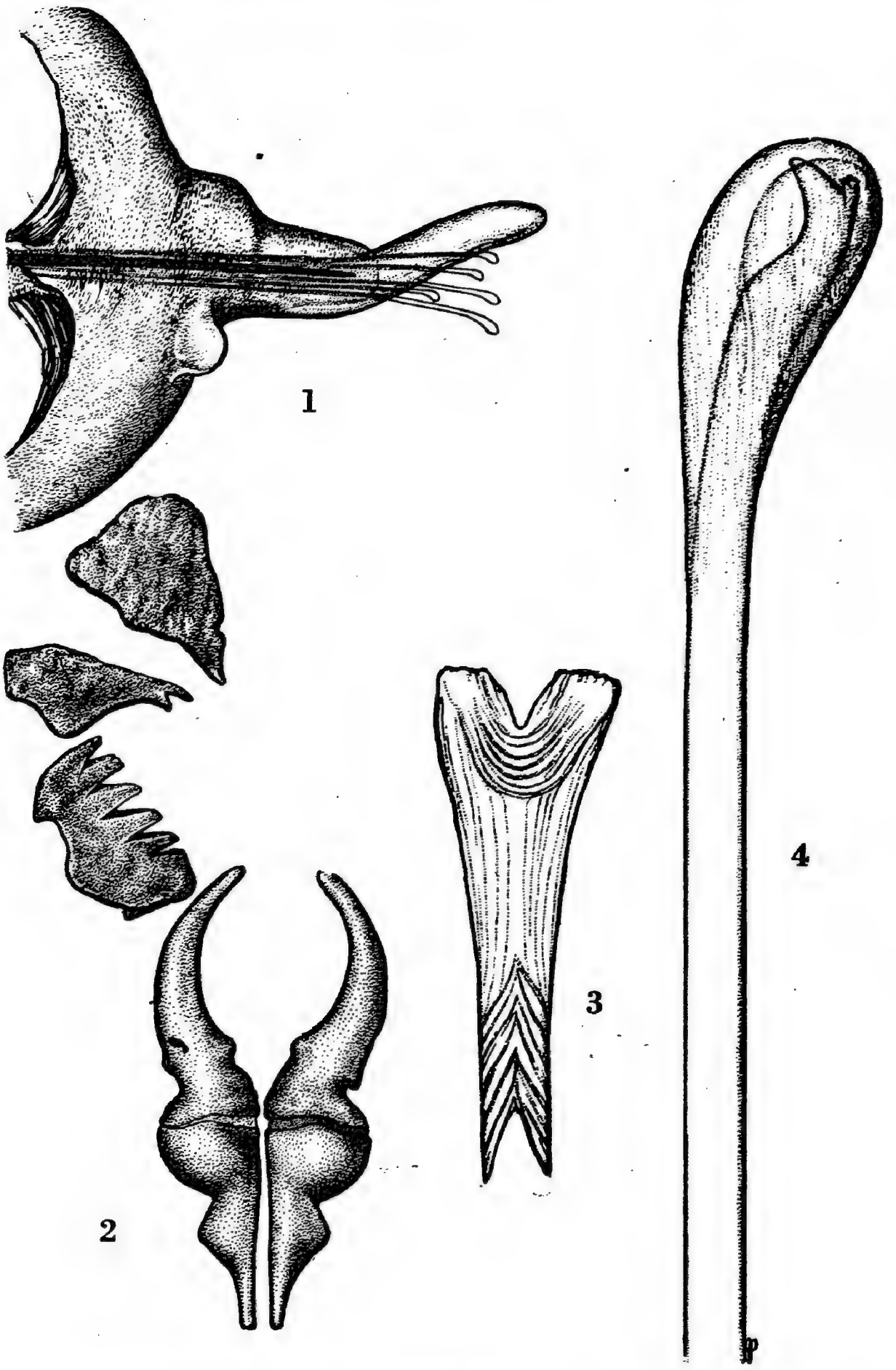


PLATE 15

FIGS. 1 to 4, *Lumbrineris alata*, n. sp.

FIG. 1, a postmedian parapodium in posterior view, x 46.

FIG. 2, maxillae including carriers, forceps and plates II to IV, seen from left side, x 50.

FIG. 3, mandible seen from dorsal side, x 50.

FIG. 4, a hooded hook from a posterior parapodium, x 883.

ends of postmedian segments, from about segment 140. These lobes emerge from the body tissue, not from the parapodia; they are composed of uniformly large cells, possibly glandular and are not penetrated by a duct.

The type locality is selected as Port Aransas, Texas. The species is further distributed in the Gulf of Mexico eastward to northwestern Florida, in littoral, sandy or silt beaches.

Lumbrinereis branchiata Treadwell (1921, pp. 94–95, pl. 8, figs. 5, 6) from Buccoo Bay, Tobago, sand, is believed to be different. According to its known account it is very long, slender, a 350 mm. long specimen consisting of 500 segments. In it the segments behind the middle of the body "have on their dorsal posterior outer angles a flattened expansion which in the living animal is filled with blood and evidently functions as a gill. These seem variable in their occurrence and may be retractile" (quoted from Treadwell, 1921). *Lumbrineris maculata* (Treadwell) (1901, pp. 198–199, figs. 42–44) from Puerto Real, might also be compared but it lacks the winged membrane and has a different maxillary formula; the postsetal lobe is prolonged already from segment 8 to 16.

Ninoë nigripes gracilis, new subspecies

Plate 16, figs. 1, 2

Ninoë nigripes Verrill, 1873 (stem species); Hartman, 1942, pp. 53–54, figs. 95–97; Hartman, 1944, p. 340, pl. 49, fig. 9.

This comes from 10 miles south of Grand Isle, Louisiana, dredged from 3 fms. in muddy bottom, Aug. 1944 (coll. Willis G. Hewatt).

An incomplete specimen of 67 setigerous segments measures 21 mm. long, is 0.66 mm. wide without and 0.99 mm. wide with parapodia. The body is uniformly cylindrical. The prostomium is a smooth, somewhat depressed conical lobe; its postmedian margin has shallow depressions marking the position of the nuchal organs (fig. 1); a pair of oval spots may represent faded eyes. The first 2 rings are subequal and lack parapodia.

Parapodial branchiae are first present from the third setiger. At the third segment there are 3 lobes including the longest dorsal one which corresponds to the postsetal lobe of more anterior segments and 2 subequal shorter ones in a vertical series. By the fourteenth setiger the number of accessory lobes has increased to 5, of which the uppermost is much the largest (fig. 2). Maximum number of branchial lobes is 7, attained at about the twenty-first parapodium. The branchiae are continued back to segment 26 after which they are abruptly absent.

The pharyngeal apparatus, seen by dissection, consists of a delicate, translucent, thin membranous mandible, similar to that of other species of the genus. Maxillae are light horny brown. The carriers and forceps are like those of the stem species, *N. nigripes* Verrill; maxilla II has 7 teeth on each side with the denticles irregular in size; maxillae III and IV on both sides have larger distal fangs and linear series of very minute denticles more proximal; those of IV are more distinct than those of III.

Parapodia are largest in the branchial region. They are provided with only simple setae and dark amber colored acicula. The first parapodium has about 3 slender, distally pointed setae; the second has 3 similar setae above and 2 long, slender hooded

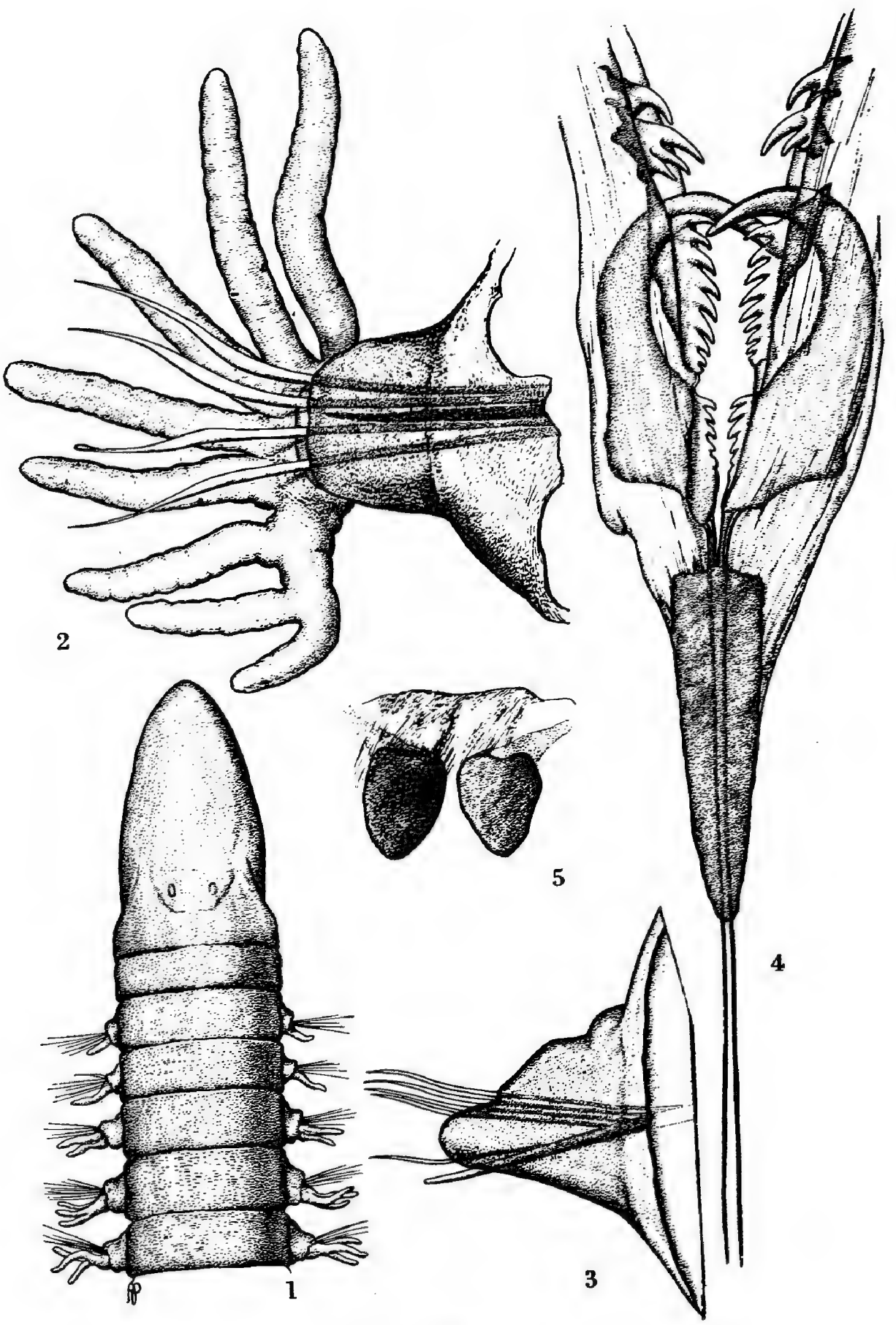


PLATE 16

FIGS. 1, 2, *Ninoë nigripes gracilis*, n. subsp.
FIG. 1, anterior end in dorsal view, x 35.
FIG. 2, branchial parapodium in anterior view, x 104.
FIGS. 3 to 5, *Drilonereis cylindrica*, n. sp.
FIG. 3, a posterior parapodium in posterior view, x 70.
FIG. 4, maxillae in ventral view, x 590.
FIG. 5, mandibles in dorsal view, x 590.

hooks below, all in a fan-shaped fascicle. Farther back the setae and hooks come to be coarser but their number does not vary except for a slight increase in those of the long, slender hooks. At the fifteenth parapodium there are 3 superior pointed setae, 3 or 2 slender hooks and a fine pointed seta below. In postbranchial segments the hooks differ in that their distal ends are coarser, with the denticles more clearly visible. The setae come to be few, only one or 2 in the uppermost part of the fascicle and hooded hooks number 2 to 4, accompanied by single, fully embedded acicula.

The subspecies, *gracilis* is similar to the stem species, *Ninoë nigripes* Verrill, from New England in the distribution of branchial processes; the 2 differ in their paragnathal formulae. *N. kinbergi* Ehlers (1887, pp. 105–106, pl. 32) from Florida Strait, 118 and 339 fms., is a much smaller species, an individual with 95 segments measures only 13 mm. long, has branchial processes through at least the fiftieth segment.

Ninoë nigripes gracilis was taken off Grand Isle, Louisiana in 3 fms.

Family ARABELLIDAE

Arabellids are long, cylindrical, reddish to brown in life, and grossly resemble a slender earthworm. They differ from the lumbrinerids (above) most conspicuously for having a different paragnathal formula and parapodia have only pointed setae in addition to acicula. Three species are recorded.

Key to Species

1. Parapodia with several embedded acicula accompanying the pointed setae; prostomium with 4 eyes in a transverse row ..... *Arabella iricolor*
1. Parapodia with single projecting acicula below the pointed setae (pl. 16, fig. 3); prostomium without eyes 2
2. Forceps of maxillary parts with teeth at the base (pl. 16, fig. 4); body pale or at least not speckled ..... *Drilonereis cylindrica*
2. Forceps of maxillae without teeth and maxilla II proportionately very small; body with diffusely scattered spots over the middle ..... *Drilonereis magna*

Arabella iricolor (Montagu), 1804

Arabella iricolor Fauvel, 1923, pp. 438–439, fig. 175; Hartman, 1945, p. 27.

An individual comes from Chadwick Beach, Sarasota Co., Florida, 1938. It is long, cylindrical, reddish brown. The prostomium has the characteristic 4 eyes in a transverse row at the posterior margin. Parapodial lobes are short throughout.

Although this species is widely known from cosmopolitan areas in temperate and tropical seas, it does not appear to be common in the Gulf of Mexico. It is associated with rocky habitats.

Drilonereis magna (Webster and Benedict), 1887

Drilonereis magna Webster and Benedict, 1887, pp. 725–726, pl. 4, figs. 60–63; Hartman, 1945, p. 27.

This comes from Bald Point, Franklin Co., Florida, sand, March, 1950 (coll. L. M. Henry) and others from Lemon Bay, Sarasota Co., Florida in muddy sand flats.

The body (preserved) is dark reddish brown except for the head and first few segments which are pale; middle and posterior regions are marked with diffusely

scattered spots on dorsal and ventral sides. Length of a nearly complete specimen is about 150 mm. The prostomium is depressed, equitriangular and has a median groove on both dorsal and ventral sides. Near the posterior end of the body the segments appear moniliform. Postsetal parapodial lobes greatly exceed the blunt presetal one; the first are somewhat bulbous at the distal end.

On the proboscis the mandibles are small, long triangular pieces. Maxillae are conspicuous for the thick, large forceps which lack teeth at their inner bases; maxilla II is proportionately much smaller and has many denticles on each side; III has 2 or 3 teeth but usually only the distalmost one is easily distinguished; IV has a single long point on each side and V is lacking.

The original description was based on a collection from Maine; it is otherwise known from North Carolina. It is not yet known from the western part of the Gulf of Mexico.

Drilonereis cylindrica, new species

Plate 16, figs. 3–5

Collections come from various parts of the Gulf side of Florida and 2 others are from Beaufort, North Carolina.

The body is long, terete, cylindrical, pale to light flesh color (preserved) except where discolored dark from surrounding black mud. An anterior piece consists of 210 segments, measures 110 mm. long and 2 to 2.5 mm. wide. Total length may attain 175 to 200 mm. and number of segments may be 250 to 300. The prostomium is depressed conical, a little longer than wide and lacks eyespots. It may have a median sulcus on its dorsal side or this may be smooth.

On the proboscis both mandibles and maxillae are present as dark horny brown pieces. The mandibles consist of a pair of subtriangular pieces about as wide as long or up to half again as long as wide (fig. 5). Maxillae (best seen by making a longitudinal incision near the middorsum, some distance behind the prostomium) consist of carriers and maxillae I to IV (fig. 4). The carriers are very long and slender, about twice as long as the ventrally located unpaired piece that is attached to the base of the forceps. The forceps are heavy, dark, strongly curved at their free ends and have a series of teeth at their proximal bases, numbering 4 to 6 on a side. Maxilla II has 8 or 9 teeth on a side; III has a long, distal fang and 2 or 3 small denticles more proximal; IV is a long, curved tooth in each side. V is not represented.

Parapodia are small, lateral and inconspicuous throughout, with the greatest development in median and postmedian segments. They are simple, papillar elevations with a short, bluntly rounded presetal lobe and a longer, triangular postsetal one which increases in size going back (fig. 3) but is never unusually prolonged or bulbous at the tip. Setae and acicula are pale yellow. Setae are distally pointed, arranged in fan-shaped fascicles; in anterior segments the projecting straight aciculum may have 2 or 3 more ventrally located setae, but in middle and posterior segments the aciculum is ventral most, projecting from the fleshy lobe of the parapodium for a considerable distance. In median segments there are about 8 to 10 simple setae and a single heavy yellow aciculum.

Posterior segments gradually become slenderer but are not moniliform. The posterior end tapers gradually to a slender anal ring that has 2 pairs of digitate lobes, 2 at each side: the anal aperture is terminal.

D. cylindrica is distinguishable from *D. magna* (above) with which it may occur, in that it lacks the speckled pattern of body segments; the forceps are dentate at the base in the first and smooth in the second; the postsetal lobes of middle and posterior body segments are different in the two.

The genus *Drilonereis* Claparède is well represented in West Indian seas and vicinity. *Drilonereis similis* Treadwell (1921, p. 111, pl. 8, fig. 12, figs. 414–417) from Tobago, West Indies, has mandibles that are short, dark, small, crescentic shaped, maxillae have forceps that are toothed at the base; maxilla II has a series of denticles and III has about 3 teeth on a side. Posterior parapodia, shown reversed by Treadwell (1921, fig. 415) so that dorsal should be ventral, have single postsetal lobes that come to be long, distally inflated and bulbous. *Drilonereis debilis* (Ehlers) (1887, p. 113) from Florida Keys in 190 fms., has mandibles that are more than twice as long as wide; maxillae III, IV and V are present, each with single long teeth. *D. brunnea* Treadwell (1921) also from the West Indies, lacks mandibles and forceps have no denticles at the base. *D. spatula* (Treadwell, 1911) from the Florida Keys, has spatulate acicula and forceps lacks denticles at the base; its parapodial lobes are distally truncate (Treadwell, 1922, p. 108).

Family LYSARETIDAE

Lysarete brasiliensis Kinberg, 1865

Plate 14, figs. 7, 8

Lysarete brasiliensis Ehlers, 1887, pp. 107–108, pl. 33, figs. 1–8.

Oenone brevimaxillata Treadwell, 1931, pp. 1–3, figs. 4–9.

A large individual comes from Alligator Harbor, Franklin Co., Florida, March, 1950 (coll. L. M. Henry) and six others, much smaller are from Lemon Bay, Sarasota Co., Florida taken from a mixed bottom, Jan. 1938. The largest is 16 inches long and posteriorly incomplete; it is up to 17 mm. wide and consists of over 400 segments. Ehlers (1887) reported an individual from Florida that was half again as long and had 490 segments.

The prostomium is broadly rounded in front; it has 3 short, simple antennae in a transverse row at the posterior margin; their tips are directed back (fig. 7); there are 4 eyes in a transverse row at the posterior margin and in line with the antennal bases. The first 2 body rings are smooth and lack parapodia. Farther back the parapodia have well developed foliaceous lobes including a dorsal one and a postsetal one (fig. 8). Setae are entirely simple, distally pointed; acicula are dark to black, embedded. The proboscidial formula resembles that of the family ARABELLIDAE (see above).

This is more widely known from eastern America including the West Indies south to Buenos Aires, Argentina (Rioja, 1944, p. 130). It is not yet known from the western part of the Gulf of Mexico.

Family DORVILLEIDAE

Representatives are usually small, 20–40 mm. long, pale or red, or transversely banded worms. The prostomium is a broad oval lobe with paired antennae and thicker, ventral paired palpi. The black jaws consist of many paired pieces in longitudinal series and may be seen through the body wall on living specimens. The

prostomium usually has 2 pairs of eyes, a larger anterior and a smaller posterior pair. Parapodia consist of notopodia represented by a long, rectangular lobe with an embedded aciculum and a shorter, distal dorsal cirrus (pl. 8, fig. 3). The larger neuropodia have simple setae and simple or compound hooks. Three species are represented.

Key to Species

1. Parapodia with simple furcate spines (pl. 8, fig. 6) ..... *Dorvillea rudolphii*
1. Parapodia without furcate spines 2
2. Parapodia with simple hooded hooks (pl. 8, fig. 4); antennae longer than palpi; red in life ..... *Dorvillea rubra*
2. Parapodia with hooks lacking hood (pl. 8, fig. 5); antennae shorter than palpi; pale in life ..... *Dorvillea sociabilis*

Dorvillea rudolphii (delle Chiaje), 1828

Plate 8, fig. 6

Staurocephalus rudolphii Fauvel, 1923, pp. 446–447, fig. 178.

Dorvillea rudolphii Hartman, 1945, p. 27, pl. 5, figs. 2, 6.

Several finds are from Lemon Bay, Florida in sandy mud beach; others are from the same locality on the Gulf side taken from a large rock submerged at low water, Jan. 1938.

In life this worm is pale or yellow but mature specimens are rose to purplish in color. The upper part of the setal fascicle has simple hooks that are deeply forked at the tip (fig. 6). The neuropodium is longest in its ventralmost lobes.

The species is otherwise known from eastern and western shores of North America and extra-American areas in littoral zones, and possibly also California whence it is described as *Stauronereis articulatus* Hartman (1938). I suspect this is at most a subspecies.

Dorvillea sociabilis (Webster), 1879

Plate 8, figs. 3, 5

Staurocephalus sociabilis Webster, 1879, pp. 243–244, pl. 7, figs. 89–91.

Dorvillea sociabilis Hartman, 1945, p. 27, pl. 5, figs. 1, 4, 5.

Several individuals come from Lemon Bay and vicinity, Florida from a mixed sandy beach and trawled from a few feet from gravel aggregates, Jan. 1938.

Color in life is pale or white with narrow red bands between segments. Parapodia have a longer, posterior postsetal lobe that is triangular in shape and a bifid presetal one in which the upper branch surpasses the lower one (fig. 3); in median segments the lower branch is sometimes obscure but in posterior segments it is obvious.

This is more widely known from Virginia and North Carolina. It is not yet known from the western part of the Gulf of Mexico.

Dorvillea rubra (Grube), 1856

Plate 8, fig. 4

Stauronereis rubra Treadwell, 1921, pp. 121–123, figs. 442–451.

Several come from Dry Tortugas and Loggerhead Key, southern Florida, June 1909 and summer 1913 (coll. A. L. Treadwell).

Length is 30 to 40 mm. Color in life is diffusely bright red in the anterior end and fading farther back. Parapodia have presetal and postsetal lobes similarly developed and longest in the uppermost parts. Superior hooks are simple, hooked, slender, delicately hooded in which the distal end is slightly falcate and has an accessory lateral tooth (fig. 4); they resemble the composite hooks but lack an articulation.

This is known only from the West Indies and Florida Keys.

Family ORBINIIDAE

These are moderately large, littoral sand-dwelling annelids, characterized for having a long, posteriorly tapering body that appears ragged because of the segmental branchiae that arises from the dorsal side. Color in life is usually pale to yellowish orange or orange-red with bright red branchiae. The prostomium is a long to short, distally acutely pointed (pl. 20, fig. 1) or broadly rounded (pl. 17, fig. 1) lobe that lacks antennae or also eyes (except in some juvenile stages). Parapodia are biramous throughout with the ventral branch most conspicuously developed and shifted upward in abdominal segments. A thorax is weakly to sharply separable from a much longer abdominal region. Eight species are recorded and others may be expected.

Key to Species

1. Prostomium broadly rounded or truncate (pl. 17, fig. 1) in front 2
1. Prostomium more or less acutely pointed (pl. 20, fig. 1) in front 4
2. Thoracic neuropodia with all setae distally pointed ..... *Naineris setosa*
2. Thoracic neuropodia with pointed setae and acicular spines (pl. 18, fig. 7) 3
3. Prostomium rounded in front; thoracic acicular spines smooth (pl. 18, fig. 7) ..... *Naineris laevigata*
3. Prostomium bifid (pl. 19, fig. 1) in front; thoracic acicular spines ornamented (pl. 19, fig. 4) ..... *Naineris bicornis*
4. Posterior thoracic neuropodia in part blunt and acicular 7
4. Posterior thoracic neuropodia with setae entirely pointed 5
5. Intercirrus (pl. 21, figs. 1, 4) present between notopodium and neuropodium in some abdominal segments 6
5. Intercirrus absent; posterior notosetal lobes large and foliose ..... *Haploscoloplos foliosus*
6. Subpodial cirrus (pl. 21, fig. 2) present below neuropodial base ..... *Haploscoloplos fragilis*
6. Subpodial area flangelike (pl. 21, fig. 5) ..... *Haploscoloplos robustus*
7. Ventral surface of some anterior thoracic segments with transverse rows of fringe, resembling prolonged papillae ..... *Phylo ornatus*
7. Ventral surface without such rows of fringe; abdominal neuropodia with projecting curved acicula (pl. 20, fig. 2) ..... *Scoloplos (Leodamas) rubra*

Naineris setosa (Verrill), revised

Plate 17, figs. 1–6

Aricia setosa Verrill, 1900, pp. 651–653.

Anthostoma latacapitata Treadwell, 1901, pp. 203–204, figs. 61–65.

Naineris setosa Hartman, 1942, p. 61, figs. 116–118.

Numerous specimens come from Englewood, Sarasota Co., Florida and 7 others are from Puerto Rico (coll. W. G. Hewatt).

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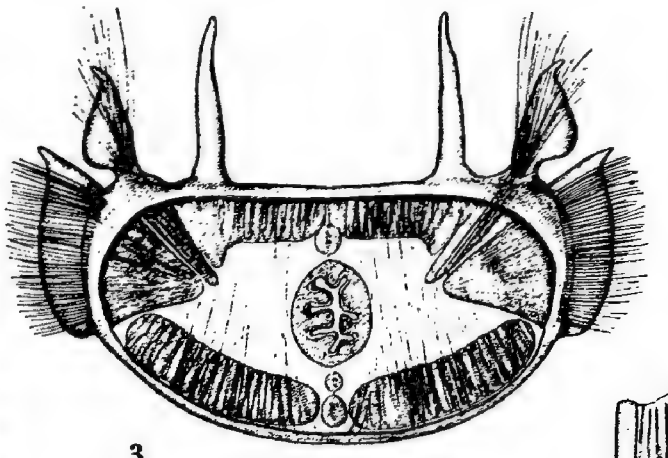

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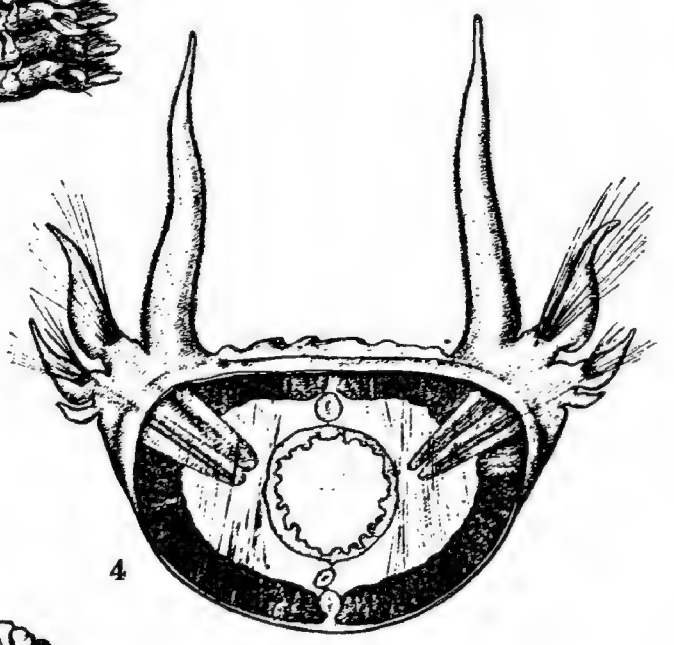

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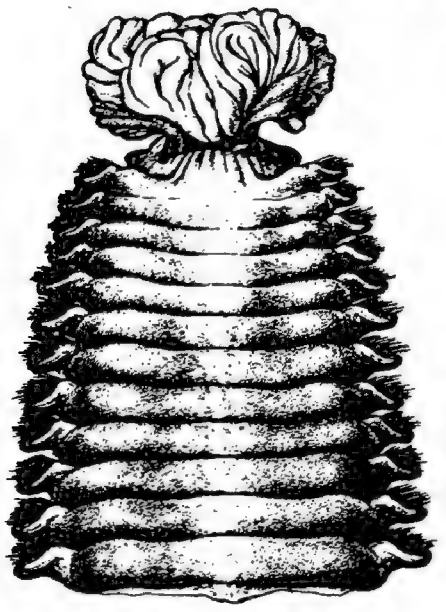

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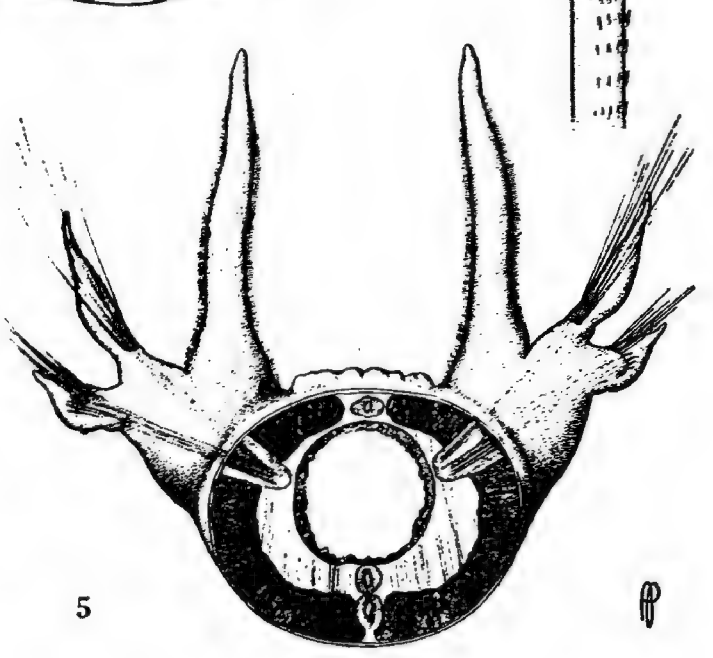

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PLATE 17

FIGS. 1 to 6, *Naineris setosa* (Verrill).

FIG. 1, anterior end in dorsal view with everted proboscis, x 7.7.

FIG. 2, anterior end in ventral view with everted proboscis, x 7.7.

FIG. 3, twelfth thoracic segment in anterior view, x 11.

FIG. 4, median abdominal segment in anterior view, x 16.

FIG. 5, a far posterior segment in anterior view, x 21.

FIG. 6, a furcate seta from a median segment, x 701.

Length of a mature female, posteriorly incomplete is 80 mm.; greatest width in the middle thoracic region is 5 mm. with and 4 mm. without parpadodia. Number of segments is over 138. The body is not sharply separable into thorax and abdomen; the first 25 to 35 segments have parapodia in which postsetal lobes are larger and setal fascicles fuller than are those farther back. Smaller specimens in the lots have similar proportions.

The prostomium is a broad, short lobe with a straight or only slightly rounded frontal margin; eyes are perhaps represented by a pair of dark, embedded spots near the posterior margin of the prostomium; a dusky area is present also on its middle. The retracted nuchal organs are minute depressions at the postectal margins; when everted they are papillar. The proboscis is a large epithelial sack that is somewhat lobed (figs. 1, 2) at its extremities but it is not dendritic.

Branchiae are first present from the sixth, or already fourth, setigerous segment and abruptly large; they are continued back to or near the posterior end of the body. They increase in size farther back and come to stand erect, or their tips may cross one another only slightly across the middorsum. The branchia is somewhat flattened and tapers to a slender tip; marginal fimbriae on both outer and inner margins are present but not conspicuous.

Paired sensory spots are visible from the fourth branchial segment; they are in front of, and just within, the branchial base near the anterior margin of the segment; they consists of a dark, transversely oval ring with a darker oval center, in thoracic segments, and circular dark areas in abdominal segments. Dorsal ciliary ridges are conspicuous across the middorsum throughout the abdominal region. The ridges extend between the bases of the branchiae but leave a short free space at the inner branchial base. They are continuous across the middorsum and may appear ruffled due to shrinking. Their presence is obvious from about the eighteenth segment.

Thoracic neuropodia (fig. 3) have full palisaded ranks of pale yellow setae; all are distally pointed; they range from longer above, to shorter ones below; those in front ranks are more bent than those in posterior rows. Each seta is somewhat knife-like and has transverse rows of spinelets. Thoracic notopodia have far fewer pointed setae and about 4 slender, tapering yellow acicula in a fascicle.

Furcate setae, not previously described, are first present in notopodia from transitional segments; where present they are few and occupy an inferior position; each has a bifurcated tip (fig. 6) with unequal distal tines and the shaft is clearly spinous along a considerable length.

Nephridial pores are visible on mature female specimens, present from the fiftieth setigerous segment; they come to be conspicuous on the posterior side of the neuropodium, through 40 to 80 successive segments, depending on the length of the individual and its approach to maturity; the nephridial apertures are directed upward.

Ventral or subpodial cirri (fig. 4) are present in anterior and median abdominal segments but absent (fig. 5) in the posterior region. Intercirri are absent.

Naineris setosa is clearly separable from other species of the genus *Naineris* Blainville for lacking acicular spines in thoracic neuropodia. In this respect it bears the same relation to other species of the genus as do those of *Haploscoloplos* (see below) to *Scoloplos* Blainville. Its separation into a new generic rank may thus be desired.

Anthostoma latacapitata Treadwell (1901, p. 203, figs. 61–65) originally described from Puerto Rico, is here newly referred to *Naineris setosa* Verrill) since the latter has priority. The account of *Anthostoma latacapitata* is to be emended in several respects. What was called "broad dorsal cirrus (second gill)" refers to the postsetal lobe of the notopodium; "dorsal seta" said to have numerous fine parallel transverse markings are believed to refer to notosetae with transversely spinous processes. A so-called bifurcated seta (Treadwell, fig. 64) refers possibly to an algal filament. The statement, "ventral setae very numerous" probably refers to those of the thorax since abdominal neuroseta are few in number. I cannot clarify the description "setae stout, narrowing rapidly to an acute point, which may be bent, or completely curved on itself, the stem marked with numerous transverse lines." Abdominal neurosetae were said to be of 2 kinds, "a few (two) blunt, rounded hardly reaching beyond apex of anterior lip [presumably acicula] and 10 to 12 delicate, long, finely toothed, with transverse lines like those of anterior dorsal setae." True furcate setae were not described but may have been overlooked since they are not readily located. With these emendations the account of *Anothostoma latacapitata* is inclusive in the genus *Naineris* and species *setosa* (Verrill). The species was earlier (Eisig, 1914, p. 450) referred to *Naineris laevigata* Grube, but the latter is a different species (see below).

Naineris setosa is known from Bermuda and Puerto Rico in addition to the southwestern Florida littoral. It is not yet known from the western part of the Gulf of Mexico.

Naineris laevigata (Grube) 1855, restricted

Plate 18, figs. 1–8

Nainereis laevigata Fauvel, 1927, pp. 22–23, fig. 7.

?Nainereis mutilata Treadwell, 1931, pp. 5–6, figs. 13–18.

This comes from the outer sands of Lemon Bay, Florida, Gulf of Mexico.

The prostomium is broadly rounded in front. Branchiae are first present from the sixth setigerous segment and continued back to the posterior end; they are simple and fimbriated along their lateral margins. Thoracic parapodia have well developed postsetal lobes (fig. 1). The transitional region is gradual between segments 16 to 20 or 24; these segments (fig. 2) differ from those in front and behind largely for a change in the size of neuropodia and number of setae. Abdominal parapodia (fig. 3) have a small, papillar intercirrus.

Thoracic neuropodia have setae that are largely of the pointed kind (fig. 4) in anteriormost segments; from the eighth segment to the end of the thorax there is a posterior row of 6 to 10 heavier, smooth acicular spines with hood (fig. 6) or without (fig. 7) that are largest above and diminish in size below with a fascicle of 6 to 8. One to several of the uppermost of these acicular spines is transitional (fig. 5). Furcate setae are present but not conspicuous, in abdominal notopodia; they end distally in subequal tines and have a spinous stalk (fig. 8).

Nainereis mutilata Treadwell (1931, pp. 5–6) from Montego Bay, Jamaica, was originally thought to be unique for having branchiae present from the first or second parapodial segment. Allowing for such obvious errors in the published account as "gill at edge of neuropodium" instead of notopodium, "notopodial lobes . . directed

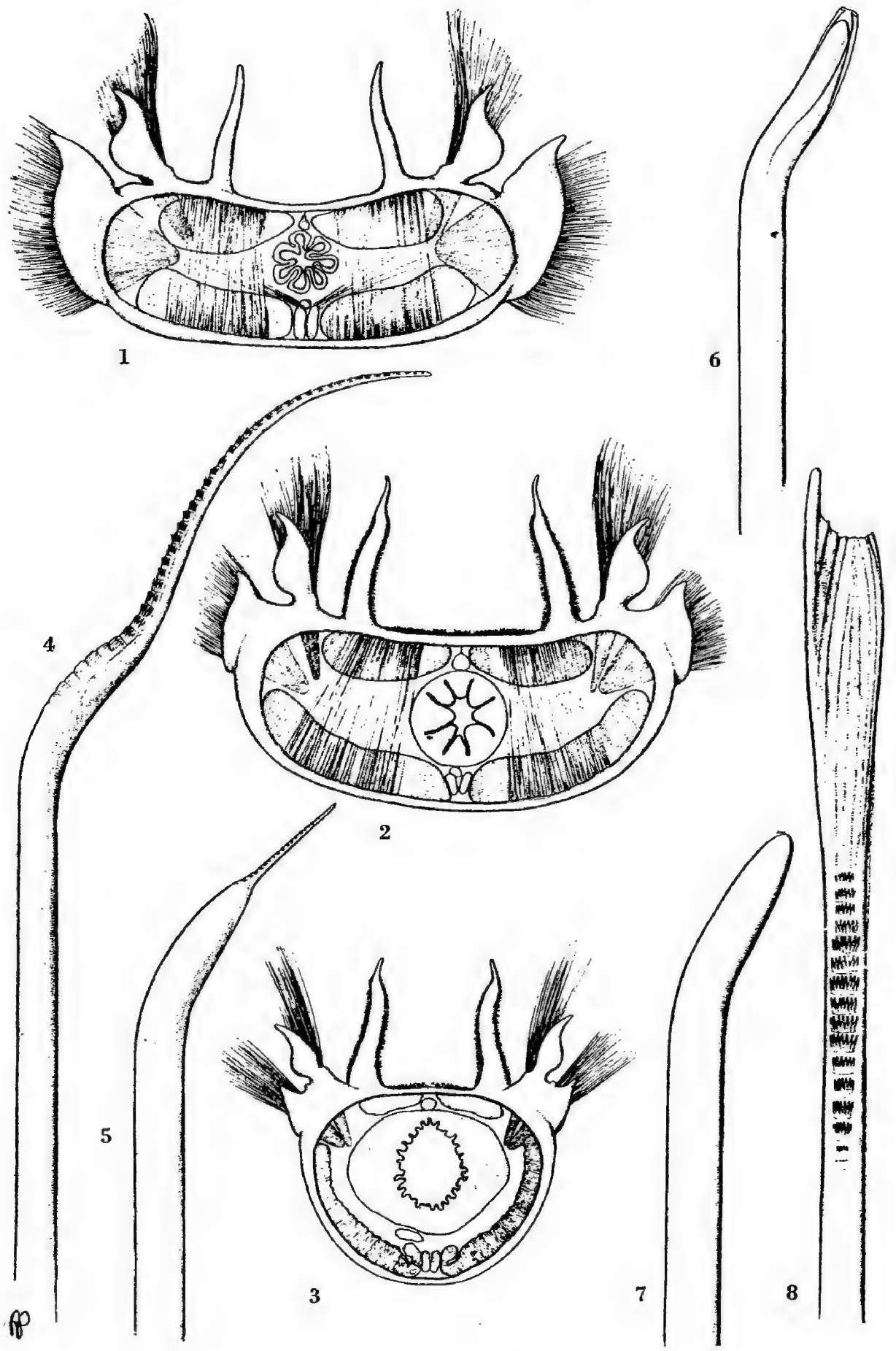

PLATE 18

FIGS. 1 to 8, *Naineris laevigata* (Grube), from Florida.

FIG. 1, fourteenth thoracic segment in posterior view, x 28.

FIG. 2, transitional thoracic segment in posterior view, x 28.

FIG. 3, abdominal segment from median region in posterior view, x 28.

FIG. 4, geniculate thoracic neuroseta seen from the side, x 1050.

FIG. 5, superiormost transitional aciculum from thoracic neuropodium, x 1050.

FIG. 6, inferiormost hooded spine from thoracic neuropodium, x 1575.

FIG. 7, posterior acicular hook from thoracic neuropodium, x 1050.

FIG. 8, furcate seta from abdominal notopodium, x 1600.

almost vertically upward" instead of branchiae directed so, "gills begin on the second setigerous somite" but shown (loc. cit., fig. 13) from the first setigerous segment, and since the acicular spines are smooth, I am inclined to regard this as based on a regenerated specimen of *Naineris laevigata* (Grube); regenerated individuals are occasionally seen in which the full complement of prebranchial segments is lacking even though prostomium and peristomium are functionally replaced.

This species has a reported cosmopolitan distribution including both sides of America and southern Europe. It is not yet recorded from the western end of the Gulf of Mexico.

Naineris bicornis, new species

Plate 19, figs. 1–6

There are 2 finds, one from Alligator Harbor, Franklin Co., Florida, February 1950 (coll. L. M. Henry) and another off Englewood Bay, Florida in sand from shallow water.

A nearly complete specimen with 103 segments measures about 30 mm. long; greatest width at the middle of the thorax is about 5 mm. The thorax consists of the peristomium and about 48 setigerous segments; transition to the abdomen is gradual between segments 45 to 50. The prostomium is broadly spatulate and bifid in front (fig. 1). A pair of small embedded dark spots, possibly eyes, is visible near the posterior margin. The everted proboscis is broad, irregularly lobed and extends well across the yentral side of the front (fig. 1).

Branchiae are first present from the sixth segment; they are small at first and gradually come to stand erect but do not cross middorsally. In shape they are compressed and taper to a slender tip; a dark glandular ridge passes along the outer convex side; the inner, slightly concave side is fimbriated and has a short basal region that is glandular. Paired, dark brown segmental spots, within the branchial bases, are first present from the fifth branchial segment and continued back into the abdominal region.

All parapodia are biramous. The first one is smallest; its notopodium has a tapering cirriform postsetal lobe and about 10 slender pointed notosetae in a close fascicle; its neuropodium is somewhat larger and has a similar postsetal lobe and about 30 slender pointed setae emergent as a spiral about the acicular papilla. The next 40 parapodia resemble one another except for gradual increase in size to about segment 30 and then decrease toward the abdominal region. A typical segment, parapodium 27, has a branchia that surpasses the notosetal lobe; the notopodium has a shorter, cirriform postsetal lobe with a knob-like expansion (fig. 2) near the middle on the outer side; these protuberances can be seen on all postsetal lobes. Notopodia have about 30 to 40 long, pointed setae with typical transverse serrations and 3 pale yellow, slender embedded acicula; the notoacicular lobe is papillar and has a slender inferior prolongation through which the acicula extend.

The accompanying thoracic neuropodia have a long flange that ends above in a short, digitate lobe (fig. 2). Neurosetae (fig. 5) are arranged in a deep palisaded row; all are pale yellow; most are long and pointed, with the longest ones in the posterior series. Acicular spines are present in a posterior row; they are distally hooded and have transverse rows of spines (fig. 4), not ridges as in some other species of the family.

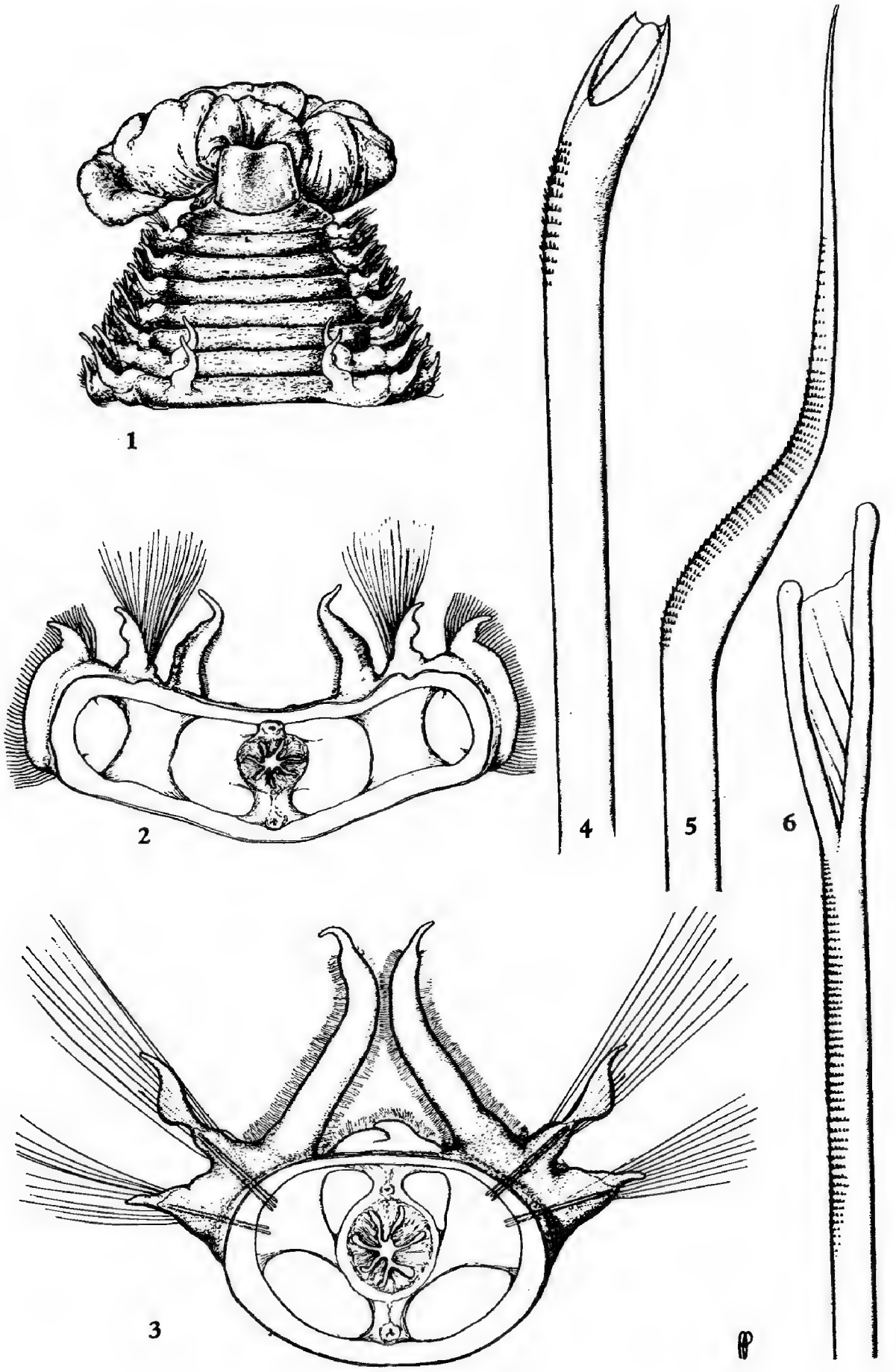

PLATE 19

FIGS. 1 to 6, *Naineris bicornis*, n. sp.

FIG. 1, anterior end with proboscis everted, in dorsal view, x 16.

FIG. 2, segment 27, showing arrangement of parapodial parts, in posterior view, x 16.

FIG. 3, a posterior segment seen from behind, x 22.4.

FIG. 4, thoracic uncinus from neuropodium 27, x 676.

FIG. 5, thoracic pointed seta from neuropodium 27, x 676.

FIG. 6, a furcate spine from an abdominal notopodium, x 676.

Abdominal parapodia are directed obliquely upward; the accompanying branchiae are large and conspicuously fimbriated at their outer margins. Notopodia are bluntly rounded and well separated from neuropodia. The neuropodium consists of distally tapering, triangular preacicular and postacicular lobes between which the setae emerge (fig. 3). There are no intercirri, ventral or subpodial cirri in any part of the body.

Furcate setae (fig. 6) are present in abdominal notopodia; they are nowhere conspicuous and number only one or a few in a parapodium. Their distal tines are unequally long and the shaft on the side of the shorter tine is spinous.

Naineris bicornis is distinguished from other species of *Naineris* Blainville for having a prostomium that is weakly bifid at its frontal margin; thoracic postsetal lobes of neuropodia terminate distally in slender filaments and their accompanying notosetal lobes have a protuberance near the middle. Thoracic uncini are proximally spinous and terminate distally in a bluntly rounded tip. Transitional uncini, such as occur in *Naineris laevigata* (see above) are absent. The thoracic region is long, with 45 to 50 segments.

This is known only from Florida, on the Gulf of Mexico side, in sands.

Scoloplos (Leodamas) rubra (Webster), 1879

Plate 20, figs. 1–6

Aricia rubra Webster, 1879, pp. 253–255, pl. 9, figs. 123–126; Andrews, 1891, p. 292.

Scoloplos (Leodamas) rubra Hartman, 1945, p. 28.

This comes from Franklin Co., Florida (coll. L. M. Henry).

It is a long, slender species, a length of about 70 mm. is only about 1 mm. wide. The prostomium (fig. 1) is acutely pointed in front and equitriangular, or longer than wide; eyes are lacking. The thorax is broadly oval in cross section and strongly depressed (fig. 3). Transition from thorax to abdomen is at segment 24 or 25 and abrupt. Branchiae are first present and already large at the sixth segment and continued back to near the end of the body; they are flattened cylindrical and terminate in slender filamentous tips.

The thorax lacks podial and subpodial papillae, also ventral cirri except that the last thoracic segment has a pointed podial papilla that is continued farther back as a prolonged postsetal lobe; this is at first located near the middle of the neuropodium but gradually moves ventrally.

Thoracic neuropodia have 3 to 5 rows of uncinial transversely ridged (fig. 4) hooks that are largest above and in the front part of the series; a few inconspicuous slender pointed setae emerge from the upper part of the fascicle. Furcate spines (fig. 6) number 2 or more in abdominal notopodia; the 2 tines are slightly unequal and smooth. Notoacicula in abdominal segments number about 3 in a fascicle; they are embedded. Corresponding neuroacicula are single, heavy, projecting curved rods (figs. 2, 5).

Segmental ciliated mounds are visible at the end of the thoracic region and come to be more conspicuous in the abdominal region. Lateral organs have not been identified an dare believed absent. Anal appendages consist of 2 longer dorsal and 2 shorter ventral processes; the latter are about half as long as the former.

Color in life is varying shades of red to orange with the middle third of the body greenish.

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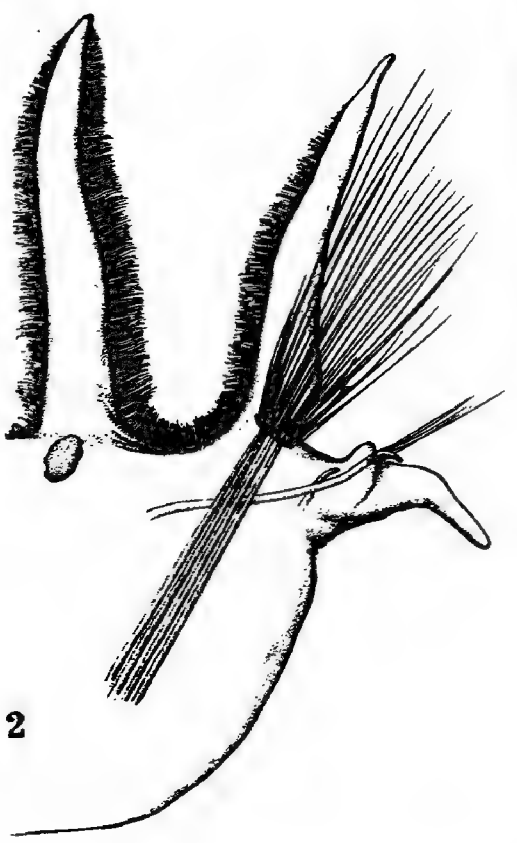

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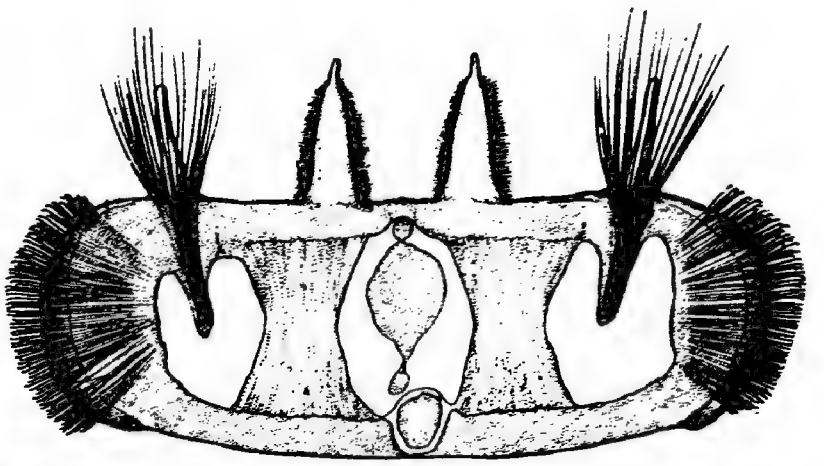

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PLATE 20

FIGS. 1 to 6, *Scoloplos (Leodamas) rubra* (Webster)

FIG. 1, anterior end in dorsal view, x 40.

FIG. 2, a far posterior parapodium in anterior view, x 83.

FIG. 3, cross section of twelfth segment seen from the front, x 63.

FIG. 4, thoracic neuropodial hook with transverse ridges, x 1316.

FIG. 5, abdominal neuropodial aciculum, x 425.

FIG. 6, abdominal notopodial furcate seta, x 2353.

Scoloplos (Leodamas) rubra ranges from Virginia southward through the West Indies and into the eastern end of the Gulf of Mexico; it occurs in littoral mud or muddy sand.

Haploscoloplos fragilis (Verrill), 1873

Plate 21, figs. 1–3

Scoloplos fragilis Verrill, 1881, pp. 301, 309, 317, 322; Andrews, 1891, p. 293.

Haploscoloplos tortugaensis Monro, 1933, pp. 261–263, fig. 10.

Scoloplos rufa Treadwell, 1941, p. 1, figs. 1–6.

Scoloplos fragilis Hartman, 1942, pp. 60–61, figs. 113–115.

Haploscoloplos fragilis Hartman, 1944, p. 340, pl. 46, fig. 5, pl. 50, fig. 6.

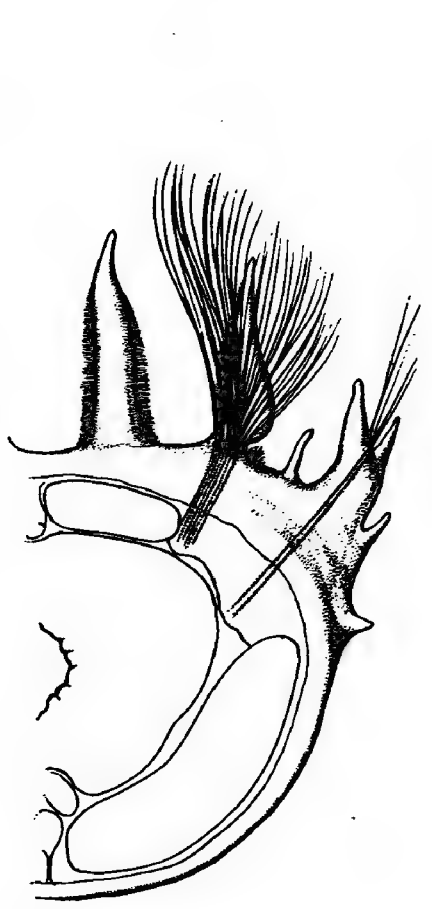
Many collections come from sandy beaches of southwestern Florida, from Franklin Co., Florida (coll. L. M. Henry) and the type specimen of *Scoloplos rufa* Treadwell, which I examined, comes from Galveston, Texas.

The prostomium is acutely pointed in front and lacks eyespots. The parapodial change from thorax to abdomen is gradual, between segments 17 to 23 or 30. Small branchiae are first present from segment 17 or not until 23 and widely spaced from each other; within a few segments they attain full size and approach one another medially. Dorsal ciliated mounds are first present in front of the first pair of branchiae; they are continued far back, located near the segmental groove.

Setae in both notopodia and neuropodia of thorax and abdomen are long, pointed, transversely spinous along their distal length. Acicular spines or uncini are absent. Furcate setae have not been identified.

An intercirrus (fig. 1) is first present between notopodia and neuropodia from the first or second branchial segment; it is cirriform and continued back through 80 to 100 segments but gradually diminishes farther back to a small papilla, in middle abdominal segments. A ventral cirrus (fig. 1) is present at the lower edge of neuropodia in transitional segments, that is, about segment 18 to 25; in addition, a subpodial lobe, located some distance below the neuropodium (figs. 2, 3) is present from the first branchial segment and continued farther back through abdominal segments. The anal cirri are a pair of long, thread-like filaments, inserted at the sides of the anal aperture and slightly ventral.

H. fragilis is believed to include *Haploscoloplos tortugaensis* Monro (1933, pp. 261–263, figs. 10 a–d) from southern Florida and *Scoloplos rufa* Treadwell (1941, p. figs. 1–6) from Offats Bayou, Galveston, Texas. The account of the first agrees fully with that of *H. fragilis* (Verrill). The holotype of *Scoloplos rufa* Treadwell, in the American Museum of Natural History, has been examined. In it the thorax consists of 22 segments with segments 23 to 30 transitional. Branchiae are first present from segment 23 and continued farther back. An intercirrus is present from the first branchial segment and present in many segments. In its original account it is described as "Another but much smaller lobe appears on the dorsal neuropodial surface." Ventral cirri and subpodial lobes agree with those of *H. fragilis*. The first account is erroneous in that the proboscis is not supported on a stalk; the illustrated fifteenth parapodium is incorrect as to lobes and number of setae; the twentieth parapodium is shown twisted



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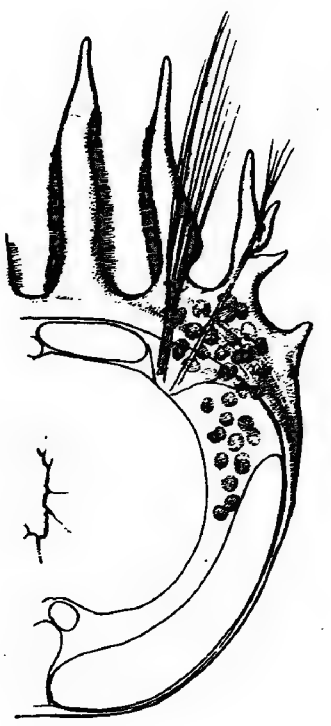

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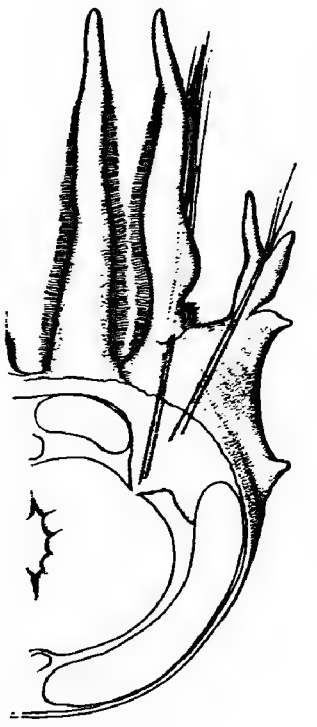

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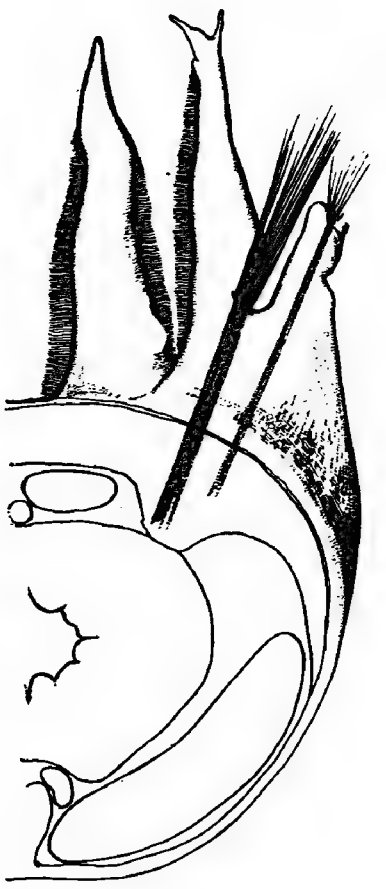

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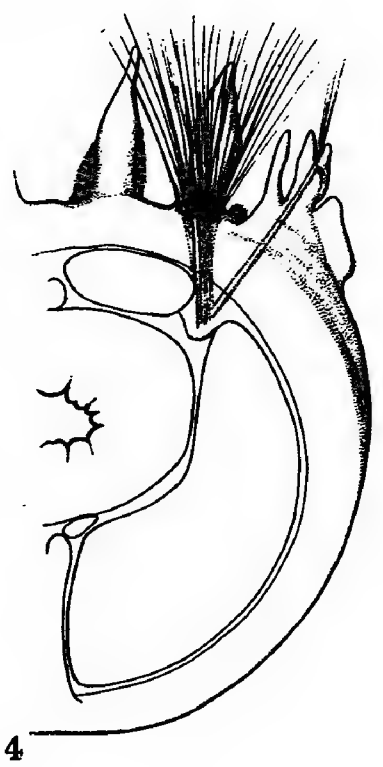

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PLATE 21

FIGS. 1 to 3, *Haploscoloplos fragilis* (Verrill).
FIG. 1, 22nd parapodium in anterior view, x 46.
FIG. 2, 69th parapodium in anterior view, x 40.
FIG. 3, a far posterior parapodium in posterior view, x 52.
FIGS. 4 to 6, *Haploscoloplos robustus* (Verrill).
FIG. 4, 28th parapodium in anterior view, x 40.
FIG. 5, 78th parapodium in anterior view, x 32.
FIG. 6, a far posterior parapodium in posterior view, x 60.

out of its normal shape so that the postsetal lobe is not visible. The original figure 5 shows not only the right half of the body with a parapodium, but in addition the branchia and base of the notosetal lobe of the other half of the body; the middorsum is thus not above, as supposed, but at the right side of the figure, and the branchiae are not double, but simple. The details of the setae shown in the figure are incorrect; they are actually like those of other species of the genus.

Haploscoloplos fragilis (Verrill) is known from New England southward to Florida and in the Gulf of Mexico west to Texas. It occurs in littoral sands.

Haploscoloplos robustus (Verrill), 1873

Plate 21, figs. 4–6

Scoloplos bustorus Eisig, 1914, pp. 422–423; Hartman, 1942, p. 58, figs. 110–112.

Haploscoloplos bustorus Hartman, 1944, p. 340.

Haploscoloplos bustoris Horn and Bookhout, 1950, pp. 1–8, pls. 1–4.

This comes from southwestern Florida, in sand. The species is clearly separable from *Haploscoloplos fragilis* (above) with which it may be associated for attaining a greater size, in having a prostomium that is less acutely pointed and for having neuropodial flanges that are entire (figs. 4–6), not divided. Branchiae are first present from about segment 23. The change from thorax to abdomen is at or near 22 to 24. Intercirri (fig. 4) are first present from the first branchial segment and continued back through 50 or more segments but absent thereafter.

Setae of both thorax and abdomen are distally pointed and transversely denticulate along the cutting edge. Furcate setae have not been identified. Color in life is orange red with bright red branchiae.

The specific name, *bustorus* Eisig (see synonymy, above) originated from the assumption that *Alcandra robusta* Kinberg (1866) and *Anthostoma robustum* Verrill (1873) were both species of *Scoloplos*. However, Kinberg's species is not a *Scoloplos* (Hartman, 1948, p.106) and Verrill's specific name is thus valid.

Haploscoloplos robustus is common in more northern parts of eastern United States, from New England south to North Carolina in addition to southwestern Florida; it is not yet reported from the western half of the Gulf of Mexico.

Haploscoloplos foliosus, new species

Specimens come from Turtle Bayou, Aransas Bay, Texas from decaying vegation or sand beaches, October, 1950 (coll. A. E. Hartman) and from Biloxi, Mississippi, sandy mud flat, shore, December, 1943 (coll. M. W. Williams).

Preserved individuals lack color; in life it may be orange red with red branchiae, as in other species of the genus. The body consists of about 200 segments and is 40 to 50 mm. long; the posterior end is closely coiled. The body is thickest in the thorax and slightly depressed; farther back it is cylindrical and tapering to the end. It terminates in a thick, collar-like pygidium with a pair of long, thread-like filaments inserted at the dorsolateral edge.

The prostomium is equitriangular, acutely pointed in front; it lacks eyes or other marks. The thorax has 17 or 18 segments; these have biramous parapodia from which the setae emerge close to the body wall; there are no lamellar or prolonged structures except for a small, inconspicuous papillar lobe emergent behind the middle neuropodial fascicle. Thoracic setae are entirely pointed and arranged in fan-shaped, spreading fascicles. The proboscis, not everted, is assumed to be voluminous and branched, as typical for other species of *Haploscoloplos*.

The transition from thorax to abdomen is at segment 17 to 19, where parapodia come to have characteristic lobes. In some individuals the body is gradually, in others abruptly, narrower at this place. Branchiae are small at first, present from segment 18, but by the next one they are as large as the notosetal lobe and continue in this size proportion through a long region; in segments far back the postsetal lobe comes to be greatly prolonged, so that the branchial tip is considerably surpassed by it. The lateral margins of branchiae have dense rows of long fimbriae; these fringes are continued proximally along the inner margins of postsetal lobes and are most conspicuous in posterior segments.

An intercirrus is altogether lacking; the only structure which might be regarded homologous is a slight fleshy boss, visible in early abdominal segments; this is not ciliated nor does it elongate in any part of the body. A ventral cirrus is likewise absent. Instead, the superior edge of the neuropodial flange, through abdominal segments, is characterized for having a slight prolongation; this comes to be set off at an increasingly greater distance from an inferior auricular lobe by segment 40, and in far posterior segments the 2 parts are abruptly set off by a constriction. Furcate setae have not been identified.

Haploscoloplos foliosus differs from other species of the genus for lacking intercirri and ventral cirri, and in having greatly prolonged neurosetal lobes in posterior segments which extend distally beyond the branchial processes.

The holotype specimen is from Turtle Bayou in Aransas Bay, Texas, from muddy sand; others are from Mississippi.

Phylo ornatus (Verrill), 1873

Aricia ornata Verrill, 1873, pp. 596–597.

Orbinia ornata Hartman, 1945, pp. 28, 30.

Two individuals come from near Englewood, Florida in sandy shoals. The thorax is divisible into an anterior region of about 14, and a posterior one of about 16 segments; these 2 are abruptly different for having modified hooks in the second region which are lacking from the first one. The transition to abdomen is abrupt at about segment 31: Anterior thoracic neuropodia have 3 to 5 vertical rows of yellow acicular hooks and a single posterior row of pointed, slightly curved setae that flank the hinder row of books. Posterior thoracic neuropodia differ from these in having shorter rows of neurosetae and the uncini of the upper half of the ramus are replaced by a single anterior row of 6 to 8 heavy, modified spines, characteristic of the genus *Phylo* Kinberg, 1866. These modified spines emerge from the uppermost part of the neuropodium, near a large parapodial gland provided with an external pore. As the spines are worn, they are replaced by new ones and the older pushed successively

down to form a vertical series of several in a row with the oldest below. The function of spines with glands remains enigmatical.

Branchiae are first present from about the fifth setigerous segment and continued back to the end of the body; they are simple and fimbriated marginally. A conspicuous ventral fringe on segments one to 18 consists of 4 to 14 digitate lobes in a single transverse row present on successive segments; this fringe diminishes in posterior thoracic segments and is absent in the abdomen. A subpodial fringe, proximal to the neuropodium, is present from about segment 15 and continued to the second abdominal segment.

Setae include long, pointed, transversely spinous ones in notopodia and neuropodia of thorax and abdomen; uncini are present in most thoracic neuropodia and accompanied by modified spines in posterior thoracic segments; furcate setae occur in abdominal notopodia.

Phylo ornatus is more widely known from New England south to North Carolina in littoral zones; in the Gulf of Mexico it has not been taken beyond Florida.

Family SPIONIDAE

The spionids are usually small, less than 50 mm. long, pale to reddish or melanistically spotted in life. The body is long, vermiform, has a pair of long, extensile palpi projecting forward. The prostomium is clearly visible unless covered by the palpi; it consists of a long dorsal lobe without eyes or with them more or less visible between the palpal bases, or limited to juvenile stages. Parapodial branchiae are usually present as simple filaments from the upper surface of notopodia or they are somewhat fused with the notosetal lobe; rarely they are lacking or accessory (pl. 23, fig. 3). Setae consist of simple pointed ones in both rami, or also simple hooded hooks in neuropodia or also notopodia.

About 30 species are recorded from eastern shores of America. At least 18 of these may be expected to occur in the Gulf of Mexico. Except for one which is injurious to oysters, the family has remained largely unknown from the Gulf. Twelve species are recorded below; one represents a new genus and species, another is a new name and most of the others are new records.

Key to Species

1. With a modified fifth setigerous segment ..... *Polydora* 6
1. Without a modified fifth segment 2
2. Median and posterior segments with accessory branchiae (pl. 23, fig. 3) ..... *Dispio uncinata*
2. Without accessory branchiae 3
3. Branchiae present on most body segments ..... *Nerine agilis*
3. Branchiae present on few segments or absent 4
4. Prostomial with frontal horns or processes at anterior margin; without parapodial branchiae ..... *Spiophanes bombyx*
4. Prostomium without frontal horns ..... *Prionospio* 5
5. Branchiae 12 pairs, each straplike or smooth, without lateral filaments ..... *Prionospio cirrifera*
5. Branchiae 4 pairs, all pinnately divided ..... *Prionospio treadwelli*
5. Branchiae 5 pairs, second and third smooth, first, fourth and fifth pinnately divided ..... *Prionospio heterobranchia texana*

6. Posterior segments have modified notopodial hooks 7
6. Posterior segments lack special hooks 9
7. Posterior notopodia have single, sickle-shaped hooks directed dorsally ..... *Polydora hamata*
7. Posterior notopodia have bundles of smooth, acicular hooks 8
8. Modified spines of posterior notopodia in close bundles; branchiae number only 5 to 7 pairs ..... *Polydora armata*
8. Modified spines of posterior notopodia alternate with pointed setae; branchial pairs more numerous ..... *Polydora caulleryi*
9. Prostomium with a median antenna at anterior end of caruncle .... *Polydora ligni*
9. Prostomium without median antenna 10
10. Prostomium with many eyespots between palpal bases; hooded hooks with obtuse distal end ..... *Polydora socialis*
10. Prostomium with few (3 or 4) to no eyespots; hooded hooks with acute distal end ..... *Polydora websteri*

Nerine agilis Verrill, 1873

Nerine minuta Treadwell, 1939, p. 5, figs. 18–20.

Nerine agilis Hartman, 1944, p. 340, pl. 50, fig. 11; Hartman, 1945, p. 31; Fauvel, 1950, pp. 371–372.

Collections come from Lemon Bay, Sarasota Co., Florida, Jan. 1938, from Grand Isle, Louisiana (coll. E. H. Behre), from near Rockport, Texas (coll. J. W. Hedgpeth) and from Alligator Point, Franklin Co., Florida (coll. L. M. Henry).

The prostomium is acutely pointed in front and has 4 eyespots in a nearly transverse line between the palpal bases. Branchiae are straplike and present from the second segment, continued back through a long region. Anterior parapodia have only pointed setae; farther back both notopodia and neuropodia have hooded hooks.

This forms beds in fine sandy beaches that shift little; the vertical burrows extend down considerably more than the length of the individual; only the distal aperture is visible at tidal recession; in some places the apertures of burrrows are very abundant and closely spaced.

Nerine minuta Treadwell (1939) from Port Aransas, Texas is here considered the same; it was originally thought distinct because of its small size, 10 mm. instead of 30–40 mm. long. This feature is characteristic of many species from the Gulf of Mexico when compared with those from colder or more northern seas. The species is widely known from New Jersey to North Carolina and French West Africa (Fauvel, 1950).

Genus *Polydora* Bosc, 1802

This genus may be well represented throughout the Gulf of Mexico. Because of the small size, the species have remained largely unknown or unreported. The history of the generic name and the distribution of fossil records in Texas are given elsewhere (see Stenzel and Turner, 1944, pp. 289–308). Six species are reported below.

Polydora websteri Hartman, 1943

Polydora ciliata Kavanagh, 1940, pp. 31–34; Kavanagh, 1941, p. 354.

Polydora websteri Hartman, in Loosanoff and Engle, 1943, pp. 70–72, fig. 1; Hartman, 1945, p. 33; Hopkins, 1947, pp. 12–14; Behre, 1950, p. 13.

This occurs throughout the Gulf of Mexico, associated with mollusk shells, serpulid tubes, barnacles and calcareous layers of rocks. It forms blisters in nacreous layers of oysters. It is intertidal and aestuarine withstanding brackish conditions. Larvae occur abundantly in the tow in November (based on collections of Dr. S. H. Hopkins).

The body is usually small, 20 mm. long or less; the prostomium is distinctly bifid in front, has 3 or 4 weakly developed eyespots or these are nearly lacking. The first segment has neurosetae but the notopodium is represented by a papillar lobe only. The fifth modified segment has 5 or 6 pairs of falcate hooks accompanied by pointed, distally flattened setae. Branchiae are present from the seventh segment to near the end of the body or the last 10 to 16 segments lack them. The pygidium is surrounded by a circular collar that is open dorsally. Hooded hooks are present from the eighth neuropodium; they terminate in a bifid tip in which the main fang is about at right angles to the shaft.

In life the body is pale or slightly flesh color; palpi have dusky or purple markings. The gallery is lined by a membranous tissue that may project from the burrow for a short distance. The tube is roughly U-shaped and large enough to permit the animal to turn about. Mud, silt and other inert materials are drawn into it to cause dark stains or mud blisters in calcareous layers.

Polydora websteri occurs more widely along eastern shores of the United States to New England.

Polydora ligni Webster, 1879

Polydora ligni Mortensen and Galtsoff, 1944, pp. 164–165; Hartman, 1945, p. 32.

Many finds are from Point Peñescal, Laguna Madre, Texas (coll. W. Armstrong Price). They come from gray mud in slimy tubes embedded in a clump of dead serpulid tubes.

Length of body is only 10 to 15 mm.; color in life is pale flesh to white. The prostomium is deeply cleft in front; there are 4 dark eyespots in rectangular arrangement. The prostomial caruncle has a median antenna inserted between the palpal bases. The pygidial collar is large and chalky white in life. Branchiae are first present from the seventh setiger and continued through few segments; they are absent from a long posterior region. The processes of tube-building are described by Mortensen and Galtsoff (1944).

This occurs more widely along both shores of North America, in littoral zones and may be considered euryhaline.

Polydora hamata Webster, 1879

Polydora hamata Webster, 1879, pp. 251–252, figs. 111–118.

Six individuals come from Bayou Rigaud, Grand Isle, Louisiana (coll. J. H. Roberts).

The prostomium has 4 dark eyes in rectangular arrangement between the palpal bases. Large, yellow dorsal hooks are present in at least 15 terminal segments; they occur singly and stand erect over the dorsum, presenting a conspicuous armature over the back. The modified hooks of the fifth segment are falcate. The hooded hooks

of neuropodia are distinctly obtuse in their distal end. This species is close to *P. hoplura* Claparède, from Europe; in the latter, however, the modified hooks of the fifth segment have an accessory process in the subdistal concavity and the hooded hooks of neuropodia are distally acute.

Color in life is white in front, brown to flesh in the middle and white or yellowish in back; branchiae are red (from Webster, 1879). The species is associated with bivalve shells. It is known elsewhere from Virginia.

Polydora socialis (Schmarda), 1861

Polydora socialis Hartman, 1941, pp. 310–311, pl. 48, figs. 41–42; Hartman, 1945, pp. 33–34.

This comes from Alligator Harbor, Franklin Co., Florida in 6 ft., Aug. 1950 (coll. H. J. Humm). It occupies a long, silt-covered tube and occurs in mud flats. Overall body length is about 10 mm. or less.

The prostomium has many small eyespots between the palpal bases; it is cleft in front. Branchiae are present from the eighth segment; they are small through several segments, larger in the middle and absent from many posterior segments. The pygidium has a broad, flaring disk with dorsal incision. The modified spines of the fifth segment are heavy, acicular, nearly straight and distally blunt. The hooded hooks of neuropodia are distally bifid, with teeth forming an obtuse angle with the shaft.

Polydora socialis is known from both sides of North America, including Chile north to California, and North Carolina.

Polydora armata Langerhans, 1880

Polydora armata Fauvel, 1927, pp. 55–56, fig. 19.

Several individuals were taken from a large shell of the Carrier-Shell, *Tugurium (Trochotugurium) longleyi* Bartsch off southwestern Florida, in 117 fms., by the M/V OREGON, station 243 (see *Eunice floridana*, above). They occupied drilled burrows, presumably made by the spionid.

The fragments are incomplete, minute, pale or white; some show at the posterior end, the spread stellate arrangement of notosetae, characteristic of the species.

This is known from southern California, western Mexico, and various parts of western and southern Europe, in addition to other widely dispersed geographic areas.

Polydora caulleryi Mesnil, 1897

Polydora caulleryi Fauvel, 1927, pp. 54–55, fig. 19.

This comes from mud and silt tubes in crevices of the Carrier-Shell, *Tugurium (Trochotugurium) longleyi* Bartsch off southwestern Florida, in 117 fms., taken by the M/V OREGON, station 243 (see *Eunice floridana*, above).

Preserved individuals are pale orange and larger than *P. armata* (above, which comes from the same mollusk). The modified spines of the fifth segment are coarse, strongly falcate and have the distal fang overhung by a fimbriated cape that appears bristled when seen from the side. The hooded hooks of neuropodia are distally bifid

with the teeth forming an obtuse angle with the shaft. This species clearly shows affinities with *P. armata* Langerhans in the character of the modified spines but they are never bristled in *P. armata,* in so far as can be observed. The ecologic niche of the two appears to be different.

This is the first record for the species from the Western Hemisphere; it is more widely known from Europe.

Prionospio ?cirrifera Wirén, 1883

Prionospio cirrifera Fauvel, 1927, p. 62, fig. 21.

Specimens come from Lemon Bay and vicinity, Sarasota Co., Florida, in old snail shell and from fine sandy beaches, Jan. 1938.

They measure 20 to 30 mm. long. Branchiae in all cases number 12 pairs, hence the questionable specific identity. They are strap-like, more or less uniformly large and abruptly absent thereafter. The prostomium is rounded in front and has conspicuous lateral flanges at its sides. A median caruncle is high and extends back to the front margin of the second segment. The 4 eyes are visible, with the 2 posterior ones much the largest.

Hooded hooks are first present from segment 18; they appear gradually in neuropodia and come to occupy most of the neuropodial ridge farther back. In notopodia the hooded hooks are first present at segment 40 and continued farther back. The anus has a large, midventral cirrus and a similar, though much shorter, dorsal process.

Prionospio cirrifera Wirén was originally described from the Bering Sea. Various redescriptions of the species, based largely on European finds, record 6 pairs of branchiae (Söderström, 1920, p. 237) and 6 to 11 pairs (Fauvel, 1927, p. 62). In the case of the specimens from the eastern Gulf of Mexico, there are always 12 pairs of branchiae; the latter may thus represent another subspecies.

Prionospio treadwelli, new name

Prionospio plumosa Treadwell, 1931, p. 3. *Not* Sars, 1873.

Prionospio tenuis Hartman, 1945, p. 32; Behre, 1950, p. 13; *Not* Verrill, 1880, pp. 176–177.

Collections come from Barataria Beach, Grand Isle and vicinity, Louisiana, July, 1942 (coll. E. H. Behre and J. H. Roberts). Others for comparison are from North Carolina.

The prostomium has 4 small, inconspicuous eyes in quadrate arrangement. Length attains 15 to 30–40 mm. All branchiae, numbering 4 pairs, are pinnately divided. There is no transverse dorsal ridge, such as occurs in some species of the genus. The first 8 segments have thick full fascicles of curved, distally pointed setae. The notosetal fascicle resembles the neurosetal one.

Abruptly from the ninth segment the neuropodium has different setae. There is a vertical series of about 12 hooded hooks that alternate with an equal number of slender, companion setae, and one inferiormost thicker, distally pointed seta that projects obliquely downward. This seta resembles the notosetae in thickness but is distally straight, not curved. Farther back this arrangement of hooks and seta is

continued but the hooks come to be more conspicuous. Notopodia continue to have pointed setae but in segments far back the long pointed ones diminish in number and are accompanied by 2 or 3 hooded hooks that resemble those in neuropodia. Uncini are hooded; they have a main fang that is at right angles to the shaft and are surmounted by a uniserial row of several smaller teeth.

This species is readily identified specifically for its abrupt parapodial change between segments 8 and 9. The nearly related *Prionospio tenuis* (Verrill) from New England, also has 4 pairs of pinnately branched branchiae. In it, however, the neuropodial hooks are not present before segment 15.

The specific name, *Prionospio plumosa* Treadwell, is here changed to *P. treadwelli*, new name, since it is preoccupied by *P. plumosa* (Sars), 1873.

Prionospio treadwelli was first described from Chesapeake Bay, Maryland in 7–48 meters, and later reported from North Carolina as *P. tenuis* by Hartman (1945). Its known range includes Louisiana.

Prionospio heterobranchia texana, new subspecies

Prionospio heterobranchia Moore, 1907, pp. 195–197, pl. 15, figs. 1–6 (stem species).

This was taken from Turtle Bayou, Aransas Bay, Texas from fine sand mixed with decaying vegetation, October, 1950 (coll. A. E. Hartman).

Length is about 12 mm. The body is pale or white (preserved) except for the black eyes on the prostomium. There are 58 segments. The prostomium is prolonged forward like a snout. There is one pair of very large dark eyes near the middle and a pair of much smaller eyespots, slightly in front and to the side of the larger ones.

Branchiae number 5 pairs; the second and third pairs are smooth and cirriform; the first, fourth and fifth pairs are plumose with the filaments numerous and laterally inserted.

Anterior neuropodia have pointed setae above and below. At the twelfth neuropodium there is one hooded hook accompanying pointed setae; at the fourteenth there are 2 hooks and farther back there is a gradual increase but the pointed setae continue to be present throughout the length (or 58 segments). In notopodia the hooded hooks are first present in segment 35 and their number increases gradually going back. The hooks resemble those in neuropodia.

The subspecies, *texana*, differs from the stem species, *P. heterobranchia* Moore, in that the latter has hooks first present in neuropodium 15, whereas in the subspecies they occur from segment 40. The prostomium has a single pair of large eyes and the anterior prolongation is not so pronounced in the stem species.

Prionospio heterobranchia texana has been taken only at Turtle Bayou, Aransas Bay, Texas. The stem species is known only from soft ooze at the deepest part of Eel Pond, Woods Hole, Massachusetts, and has not been recorded since first described (1907).

Spiophanes bombyx (Claparède), 1870

Spiophanes bombyx Fauvel, 1927, p. 41, fig. 14; Hartman, 1945, p. 31.

This comes from the Gulf of Mexico side of Lemon Bay, Florida and others for comparison come from North Carolina.

The prostomium is a broad, triangular lobe that is widest in front and has attenuate lateral processes or horns. The 4 eyespots are in trapezoidal arrangement, with the anterior pair wider apart. The first ciliary transverse ridge is on the third segment.

The first neuropodium has a pair of heavy spines, distally curved and directed downward. Uncini are first present from segment 16; they are in vertical series of about 8 in a row, accompanied by a long, pointed seta in the lowest position. All setae before the 16th segment are distally pointed. Hooded hooks are distally bifid with the main fang at about right angles to the shaft, not obtuse, as in the European species (see Fauvel, 1927, fig. 14e). The accessory or more distal tooth is much the smaller.

Spiophanes verrilli Webster and Benedict (1884, pp. 728–729) from Massachusetts, low water, is a different species. Earlier I (1945, p. 31) had regarded them as possibly the same. They are different in that the hooded hooks are already present from segment 6 in this, and not before segment 16 in *S. bombyx;* dorsal ciliary ridges are first present on segment 6 in the first and from segment 3 in the second.

Spiophanes bombyx (Claparède) is more widely recorded from Europe (see Fauvel, 1927, p. 41).

Genus *Dispio,* new

Type *D. uncinata,* new species

The prostomium is rounded in front; its caruncle extends back only to the first segment. There are 2 pairs of small, inconspicuous eyes at the sides, largely concealed by the palpal bases. The palpi are paired, large, thick, longitudinally grooved. The lateral margins of the peristomium at the sides of the prostomial ridge, are enlarged to form flanges that extend back to the first setiger. Branchiae are present from the first setiger and continued back to the posterior end; they are more or less fused with the postsetal, notopodial lobe.

All parapodia, including the first are biramous. Notosetae are entirely simple, distally pointed. Neurosetae are similarly pointed in anterior segments; farther back some of the pointed setae are replaced by hooded hooks that end distally in an entire point and are hooded. The pygidium ends in a simple, collar-like ring with a slight middorsum notch.

From about the twentieth segment there are paired accessory branchial tufts that arise from behind the notopodial base; these tufts have 2 to 5 digitately arranged lobes, each with a vascular loop. The notopodial lobes of the first few segments are enlarged and distally serrated.

Dispio grossly resembles *Spio* Fabricius in having branchiae on all segments and hooded hooks only in neuropodia. The prostomium is similarly prolonged in front and lacks frontal horns, and parapodial branchiae are somewhat fused to postsetal lobes. *Dispio* differs for having accessory branchial lobes and the first few notopodial lobes are serrated. *Dispio* resembles *Nerine* Johnston in having hooded hooks that are distally entire, and branchiae fused with notopodia, but in *Nerine* the notopodia in posterior segments have hooks and branchiae are absent from the first segment. *Polybranchia* Potts (1928, pp. 693–694) has accessory palmate branchial lobes that resemble those of *Dispio,* but this genus, known for the single species, *P. foxi* Potts, differs so sharply from other spionids that it may belong elsewhere; notable are the lack of pointed setae and parapodial lamellae.

Dispio uncinata, new species

Plate 22, figs. 1–5; plate 23, figs. 1–4

Spio setosa Behre, 1950, p. 13.

There are 7 individuals; they come from Alligator Point, Franklin Co., Florida, March, 1950 (coll. L. M. Henry) and Grand Isle, Louisiana, sandy beach, July, 1942 (coll. E. H. Behre and J. H. Roberts).

Length of a complete specimen (preserved) is 32 mm. for 120 segments; width is 2 to 2.5 mm. at the middle or widest part. A larger specimen that is posteriorly incomplete measures 30 mm. long for 70 segments. There is no color remaining on fixed materials except for that on the palpi.

The prostomium is prolonged forward and its anterior, subtriangular part is slightly set off by a pair of lateral emarginations from the larger, lateral lobes that comprise the peristomium. The prostomium extends back between the palpal bases and is only slightly prolonged as a caruncle to the end of the first segment to form a nuchal ridge or enlargement. The raised lateral flanges of the peristomium extend lengthwise along the prostomial ridge (pl. 22, figs. 1, 2).

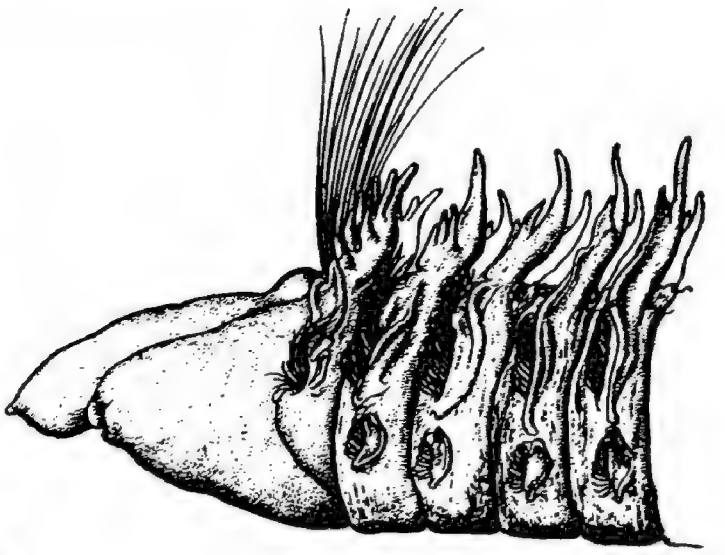
Palpi are thick, longitudinally grooved, marked by widely spaced black transverse bars on the side opposite the longitudinal groove. Four prostomial eyes are present but largely concealed in the grooves between the prostomial caruncle and palpal bases; they are in trapezoidal arrangement with the anterior pair the wider apart.

The first 3 pairs of parapodia differ from those farther back in that their superior notopodial parts are deeply serrated; this serration is most conspicuous in the first segment. The first one (pl. 23, fig. 2) has a large notopodium with a long branchia that is continuous with a series of 5 or 6 serrations which diminish in size gradually and merge with the frilled postsetal membrane; the presetal lobe is much smaller and attached near the base of the large postsetal process. Between these 2 lobes emerge 30 to 50 long, slender setae that are directed upward. The setae are longest at the upper end of the fascicle and diminish gradually going down. The notopodial processes of the first pair thus form a palisaded series behind the palpal bases. The neuropodia of the first segment are much smaller than notopodia; each consists of a weakly lobed foliaceous postsetal lobe; it carries about 20 slender setae, including 9 shorter ones directed laterally and 6 or more longer ones in an inferior tuft.

Farther back the second and third notosetal lobes are similarly serrated but decreasing in the number of lobes so that by the fourth and fifth segments the divisions have disappeared.

The second notopodium has a superior tuft of about 6 slender setae similar to that of the first but shorter, and 6 pairs of shorter setae below; each of the pairs includes a broadly limbate one and a slenderer companion seta inserted slightly behind the broader one, together forming a double vertical series. In addition, there are 2 or 3 ventralmost, long pointed setae extending out far beyond the others. The arrangement of setae from the third segment is similar to that of the second except that the larger pointed setae come to be more broadly limbate. In all segments the longest setae are the 2 or 3 uppermost in notopodia, and the 2 or 3 lowermost in neuropodia. In the twentieth segment there are 3 long pointed setae and about 10 pairs of shorter ones in notopodia. Neuropodia have about 11 pairs of shorter ones and 3 slender lowermost ones.

1



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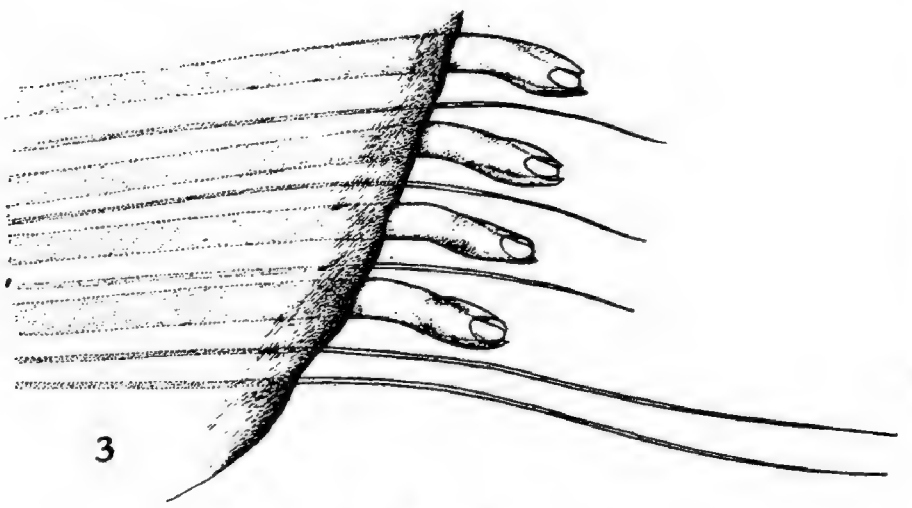

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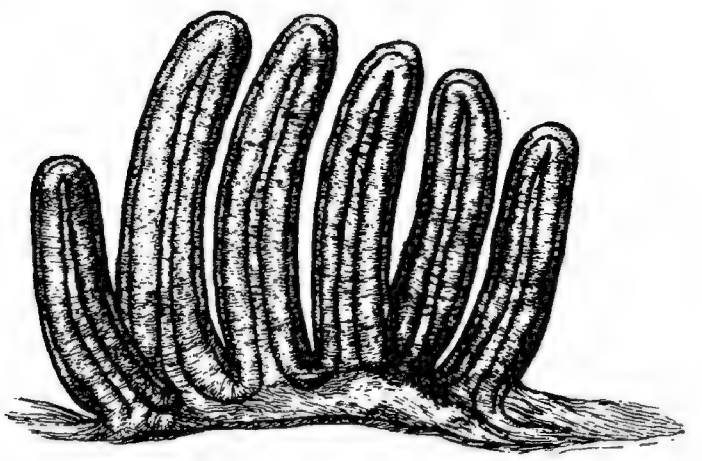

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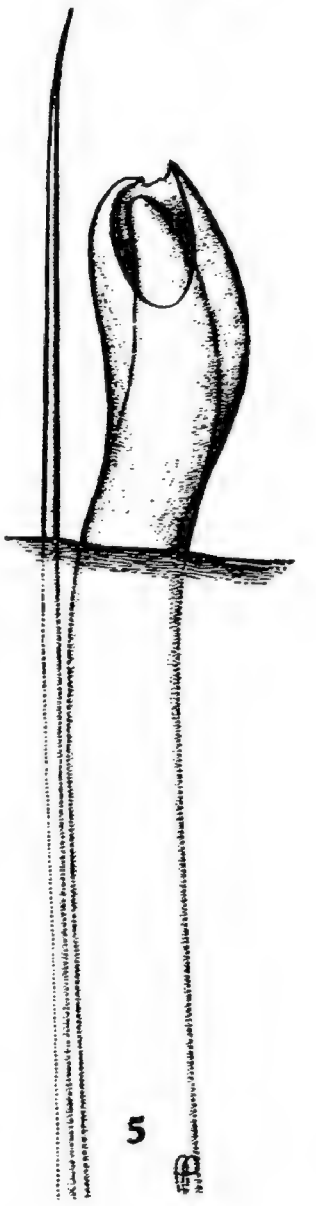

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PLATE 22

FIGS. 1 to 5, *Dispio uncinata*, n. gen., n. sp.

FIG. 1, anterior end in dorsal view, showing prostomium and first five segments, x 22.

FIG. 2, anterior end in left lateral view, showing prostomium with first five segments, x 22.

FIG. 3, series of hooded hooks with companion setae and two inferiormost setae, x 239.

FIG. 4, an accessory branchial tuft showing arrangement of vascular loops, x 234.

FIG. 5, a hooded hook and companion setae from a posterior neuropodium, x 526.5.

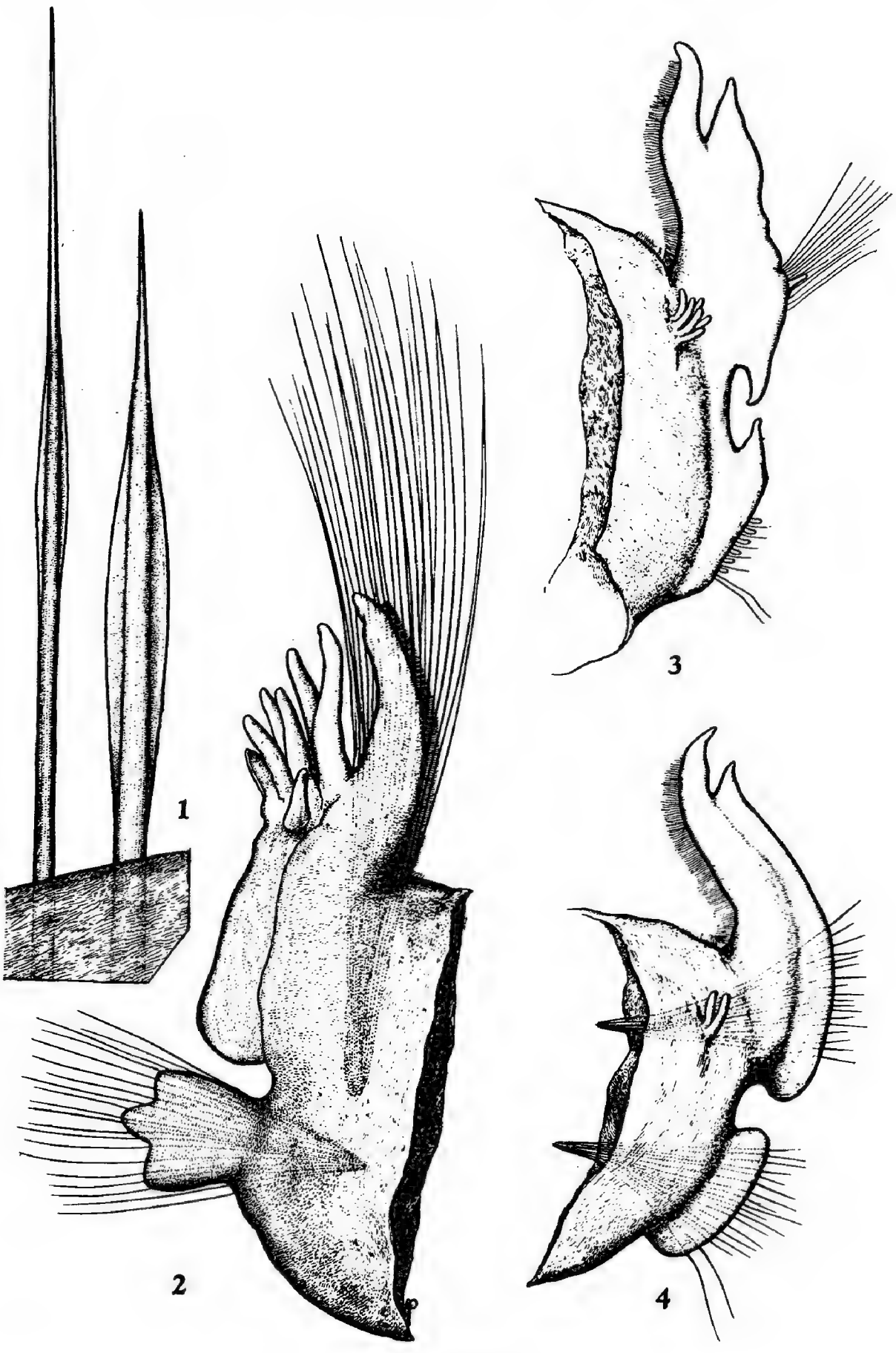


PLATE 23

FIGS. 1 to 4, *Dispio uncinata*, n. gen., n. sp.

FIG. 1, a pair of notopodial setae from a median parapodium, x 368.5.

FIG. 2, first parapodium from left side, in posterior view, x 75.

FIG. 3, a posterior parapodium in posterior view, x 35.

FIG. 4, twenty-fourth parapodium in posterior view, x 35.

From segment 25 to 27 the neuropodial paired setae are replaced by hooded hooks (pl. 23, fig. 3) but the tuft of 2 or 3 slender setae remains as before. The hooks occur in single series of 5 to 8 in vertical rows, and are continued to the posterior end; they are accompanied by slender pointed setae (pl. 22, fig. 3) like those in front (pl. 23, fig. 1), alternating with the hooks. The hooded hooks are distally entire, slightly curved and the hood extends distally to or slightly beyond the point (pl. 22, fig. 5).

Parapodial lamellae are well developed. The presetal ones are short, auriculate; the postsetal lobes are longer but do not extend out as far as setae or hooks. They are more or less completely fused with the branchial processes along their upper sides but the distal ends are free (pl. 23, figs. 3, 4). Postsetal lamellae of the first few segments are frilled and larger than those in back.

Branchiae are present from the first segment to the end of the body. They are fused with the notopodial postsetal lobe (pl. 23, fig. 3); their inner proximal edges have long fringe that is continued along the base of the parapodium and onto the dorsum of the body. In the middorsum of each segment there is a band of similar long fringe, in line with that of the branchial row.

The anal end tapers gradually to a short, narrow collar with a slight middorsal notch and a posterior aperture; there is no flange or cirrus.

Accessory branchiae are first present from segment 24–28, as simple long lobes that arise from the dorsolateral side of the body behind the notopodial base. The number of lobes increases gradually to 6 or 8, arranged in palmate group (pl. 22, fig. 4). Each loop contains a vascular flexure that is continuous with successive ones so that the entire branchia may be considered a prolonged vessel that is thrust into a series of curvatures. This accessory vessel connects, not with the branchial loop in parapodia, but with a lateral vessel in the body. The accessory branchiae appear to be non-retractile (pl. 23, figs. 3, 4).

Large, elongate oval discs, representing nearly ripe ova, fill the body cavity; each is covered with a thick sculptured shell.

Dispio uncinata is known only from Alligator Point, Florida, sand and from Grand Isle, Louisiana (reported as *Spio setosa* by Behre, 1950).

Family MAGELONIDAE

These spioniform annelids differ from the SPIONIDAE chiefly for having greatly prolonged paired palpi that are conspicuously papillated. The thorax is set off from the abdomen by a ninth segment in which the setae differ from those in front and back. Both notopodia and neuropodia in the abdomen have hooded hooks. A single species is reported.

Magelona, near *californica* Hartman, 1944

Magelona californica Hartman, 1944, pp. 320–321, pl. 28, figs. 10–14.

Six specimens come from Alligator Harbor, Franklin Co., Florida, June, 1950 (coll. L. M. Henry).

The prostomium lacks frontal horns. The ninth or modified segment has full spreading setal fascicles with setae distally tapering and pointed. Abdominal hooks

are distally bifid with the main tooth at a sharp angle to the shaft and the secondary tooth nearly as large as the main one.

The formalin-preserved specimens retain no color except for paired speckled areas on the dorsal side of the thorax; there is no lateral pigment in the abdomen such as occurs in *M. californica,* from California.

Magelona rosea Moore (1907, pp. 201–204, pl. 16, figs. 24–30) from New England is a different species; in it the abdominal hooks are much less sharply beaked distally and the secondary tooth is smaller; the paired pigment patches of the thorax are lacking; the prostomial lateral flanges are obliquely ridged and ventral cirri are present on the tenth parapodium.

Magelona californica is elsewhere known from central and southern California.

Family CHAETOPTERIDAE

Two species are reported.

Key to Species

1. Larger, in U-shaped, opaque tubes ..... *Chaetopterus variopedatus*
1. Smaller, in long, slender, annulated, translucent tubes .... *Spiochaetopterus oculatus*

Spiochaetopterus oculatus Webster, 1879

Spiochaetopterus oculatus Webster, 1879, pp. 247–249, pl. 8, figs. 98–102; Hartman, 1945, p. 35.

Numerous finds come from northern shores of the Gulf of Mexico, from near Biloxi, Mississippi in sand flats with oysters, Dec. 1943 (coll. M. W. Williams), from Barataria Bay and Caminada, near Grand Isle, Louisiana, 1942 and 1948 (coll. J. H. Roberts).

The tube is characteristic, cylindrical, transclucent, annulate, resembling a delicate straw; it may be several inches long and only a mm. across; the distance between successive annulations ranges from 0.5 to 2 mm. On the worm there is a dark spot on the ventrum between segments 6 and 7, followed by a chalky white ventrum on segments 7 to 9.

The species is more extensively recorded from New England south to North Carolina.

Chaetopterus variopedatus (Renier), 1804

Chaetopterus pergamentaceus Leidy, 1888, pp. 73–74.

Chaetopterus variopedatus Fauvel, 1927, pp. 77–79, fig. 26; Hartman, 1945, pp. 34–35.

This occurs in low channels in mud flats near Englewood, Florida; the tubes are large, U-shaped and open to the surface at both ends. It is parchment like and opaque. Commensal crabs of the genera *Polyonyx* and *Pinnixa* (Hartman, 1945, p. 35) are apt to be found in the tube.

The species has a very wide, cosmopolitan distribution and is known from New England southward; it has been noted at the mouth of the Manatee River, Florida (Leidy, 1888).

Family CIRRATULIDAE

Four species in three genera are recorded; two are newly described.

Key to Species

1. Penetrating shells; dark green to black in life; lateral tentacles few, limited to anterior end 3
1. Not penetrating shells; lateral tentacles few to many 2
2. Posterior segments provided with only pointed setae (pl. 25, fig. 3) ..... *Cirratulus hedgpethi*
2. Posterior segments provided with blunt, acicular hooks ..... *Cirriformia filigera*
3. Paired tentacles number less than 5 pairs ..... *Dodecaceria diceria*
3. Paired tentacles number more than 10 pairs ..... *Dodecaceria*, near *concharum*

Dodecaceria diceria, new species

Plate 24, figs. 4, 5

Many specimens were removed from drilled runways in the nacreous layers of a large living shell of the Carrier-Shell, *Tugurium (Trochotugurium) longleyi* Bartsch off southwestern Florida in 117 fms., taken by the M/V OREGON, station 243 (see *Eunice floridana*, above).

Preserved and possibly also in life the color is very dark green to black. The body measures 12 to 15 mm. long, about 0.3 to 0.5 mm. wide at the prostomium and 0.6 to 0.8 mm. wide in the middle third or widest part. The segments number more than 100 and are closely crowded at the posterior fourth to end of the body. Under magnification the body rings are seen to be crossed by 6 to 10 closely crowded rings and splashes of dark color. These marks obscure the segmental furrows.

The prostomium is a short, triangular lobe (fig. 4) a little wider than long; it has a pair of nuchal slits at the postectal margins; there are no eyes. The prostomium is indistinctly separable from a longer, smooth, preantennal region; on the ventral side its anterior end forms the lower lip.

The first body ring is only about half as long as the peristomial ring. From its anterior margin, at the dorsoectal ends there is a pair of thicker, longer, cylindrical filaments and a similar, slenderer, shorter pair inserted immediately within (fig. 4). A wide space separates these filaments so that the middorsum is exposed. In most specimens only these 2 pairs of tentacular processes are present, hence the specific name. An occasional individual has in addition a very much shorter, smaller pair of filaments inserted behind the first pair but on the following segment.

Setae and hooks are nowhere conspicuous and are usually not readily seen because of the deeply pigmented epithelium. The first setiger has about 4 long setae in notopodia and 3 in neuropodia. The second has 2 larger and 2 slender setae in notopodia and 3 larger with a slenderer in neuropodia. The third segment has one larger and 2 finer setae in notopodia and one larger and 3 slenderer ones in neuropodia. After that there is less difference in size between the finer and coarser setae. The first 10 segments have only pointed setae. Simple falcate hooks (fig. 5) are present from about the eleventh segment and alternate with longer setae in both rami. In one individual that was minutely examined, segment 11 has 5 pointed setae above, and 4 setae with 2 hooks below; segment 12 has 4 setae and 2 hooks above and 5 hooks below; segment

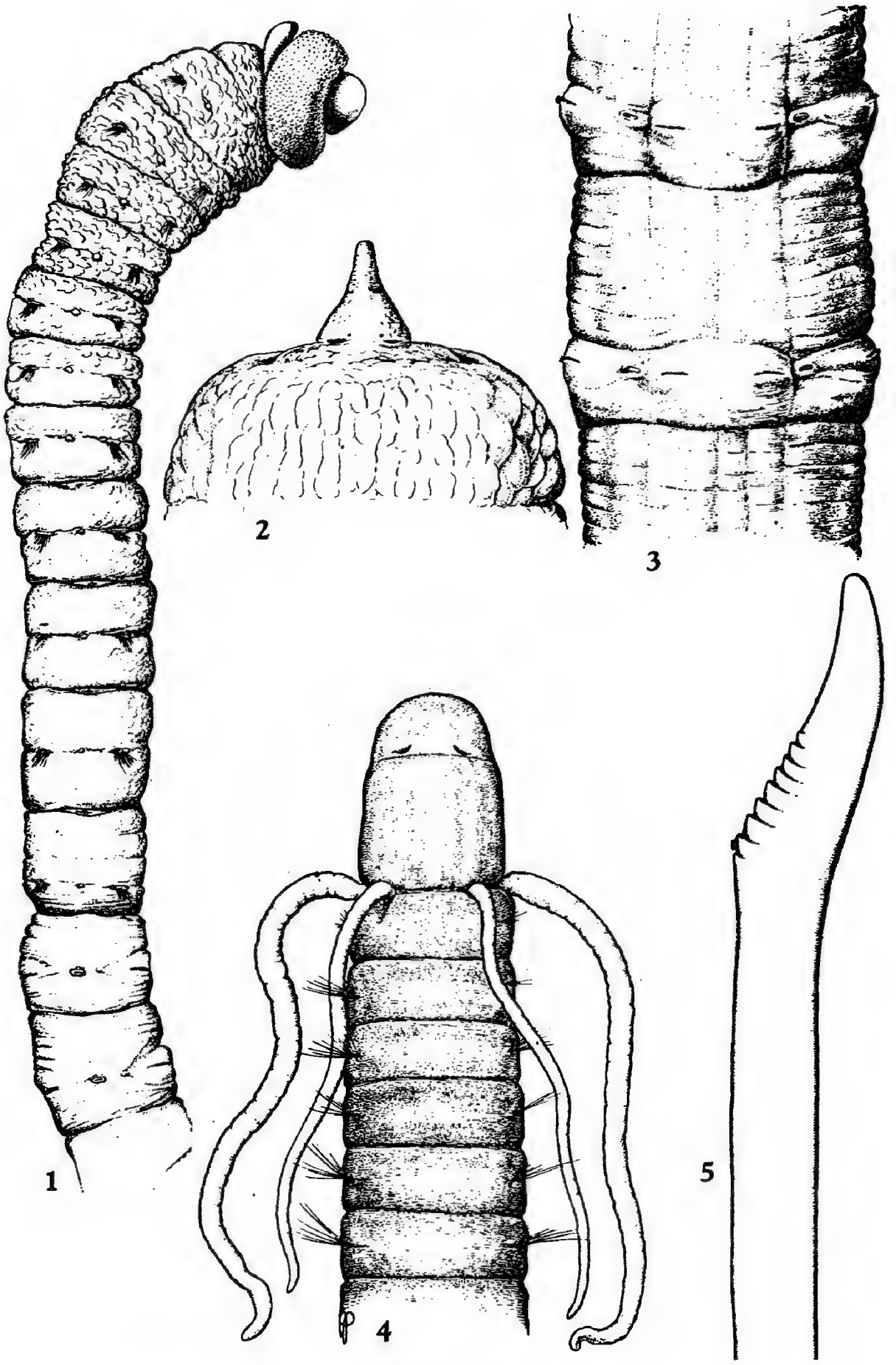


PLATE 24

FIGS. 1 to 3, *Notomastus hemipodus* Hartman.
FIG. 1, anterior end including thorax and first 2 abdominal segments, seen from right side, x 28.
FIG. 2, prostomium and peristomium, seen from the top, x 66.
FIG. 3, median abdominal segments seen from above, x 56.
FIGS. 4, 5, *Dodecaceria diceria*, n. sp.
FIG. 4, anterior end in dorsal view, x 64.
FIG. 5, a parapodial hook seen from the side, x 1485.

13 has both setae and hooks above and 6 hooks below. Farther back the presence of the hooks and setae in both rami can usually be distinguished and there is a gradual diminution of parts going posteriorly.

The hooks (fig. 5) are distally falcate and have a series of 7 or more transverse ridges at the geniculate region. The posterior end of the body terminates in a slender tail with a distal aperture. Some individuals show indications of anterior regeneration of the first 10 or more segments.

The genus *Dodecaceria* Oersted is known for few species. Some, such as *D. concharum* Oersted, penetrate calcareous structures, others, such as *D. fistulicola* Ehlers, construct limey matrices. *D. diceria* belongs to the group which destroy shells. It differs from all known species in having its tentacular processes limited to only 2 pairs; its acicular hooks are transversely ridged instead of ladle-shaped.

Dodecaceria diceria is known only off the western end of the Florida Keys in 117 fms.

Dodecaceria, near *concharum* Oersted, 1843

Dodecaceria concharum Fauvel, 1927, pp. 102–103, fig. 36.

One dark olive green specimen comes from Alligator Harbor, Franklin Co., Florida, March 1951 (coll. D. Carpenter). It has 29 segments, is posteriorly incomplete, and measures 8 mm. long and about 1.3 mm. wide. The paired palpi are followed segmentally by 8 pairs of long filamentous cirri and these by 4 much shorter pairs that come to be gradually shorter going back. Anterior segments have only long, pointed setae in notopodia and neuropodia; these are almost wholly replaced by pale yellow hooks in the third post-tentacular segment. It differs from typical *D. concharum* Oersted in having more tentacular cirri and pointed setae through a longer region.

Cirriformia filigera (delle Chiaje), 1841

Audouinia filigera Fauvel, 1927, pp. 92–93, fig. 32.

Cirriformia filigera Hartman, 1945, p. 35.

About 25 specimens were trawled near the pass in Lemon Bay, Sarasota Co., Florida, Jan. 1938, from gravel aggregates and another was taken from a low tide mud flat, near Englewood, Florida at the same time.

The prostomium is a conical lobe lacking eyespots. The numerous dorsal tentacles arise across the middorsum of the third or fourth setigerous segment. Lateral tentacles are continued on body segments; they are first present from the first setiger, proximal to the notopodium. In median and posterior segments their origin is gradually upward so that they are well removed from the notopodial papilla. Acicular setae are yellow, present in both notopodia and neuropodia in middle and posterior segments; they number 2 to 5 in a series and alternate with slender pointed setae.

Cirriformia filigera occurs more widely on both sides of the North Atlantic Ocean and south to Brazil.

Cirratulus hedgpethi, new species

Plate 25, figs. 1–3

A large, dark brown (preserved) specimen, complete though broken in the middle comes from a bell buoy in 4–5 fms., off Port Aransas, Texas, October 22, 1946 (coll. J. W. Hedgpeth); another posterior fragment is from Port Aransas, Texas, November, 1948 (coll. J. W. Hedgpeth).

The body is thick, much coiled, over 200 mm. long and 8.5 mm. wide in the front or at greatest width; it consists of more than 300 segments. It is somewhat depressed in front, cylindrical farther back or somewhat depressed (fig. 2) and tapers to a slender posterior end with terminal anus.

The prostomium is broadly rounded in front (fig. 1); eyes are not visible and presumably absent; nuchal organs are visible as crescentic depressions at its postectal margins. The presetigerous region is long, crossed by 6 to 8 deep wrinkles of contraction; complete segmental rings are lacking.

The first setigerous segment is biramous; it has on either side, immediately above the notopodial tuft, a reduced bundle of slender branchial filaments that number only about 4 pairs (fig. 1); these filaments are unusually slender and short for a cirratulid; leaving bare a broad, median space. Farther back the lateral tentacles are very few, slender and inserted slightly above the notosetal tuft, at least to the middle of the body. Farther back I was unable to make out any lateral tentacles or scars marking their possible surface of attachment.

Setae are entirely long, distally pointed. Those in front are in greatest number and farther back they gradually diminish in number and length. There are 2 kinds (fig. 3), including a thicker, somewhat coarser one and an alternating finer one, arranged in a double series. Both are pale amber, smooth and finely pointed at the tip. There are no blunt acicular or curved spine-like setae in any part of the body.

Cirratulus hedgpethi belongs to the group of species in which parapodia have only slender, pointed setae. *Cirratulus elongatus* Treadwell (1901, p. 204, fig. 56) from Culebra is said to belong here, but it has a prostomium that is acutely pointed in front and the presetigerous region has 3 complete annulations. *C. filiformis* Keferstein (Fauvel, 1927, pp. 94–95) also belongs to this group but agrees with *C. elongatus* in the characters named above. *C. hedgpethi* is further characterized for the greatly diminished dorsal and lateral tentacles and a broadly rounded prostomium that lacks eyes.

I take pleasure in naming the species for Dr. Joel W. Hedgpeth to whom I am indebted for the finds.

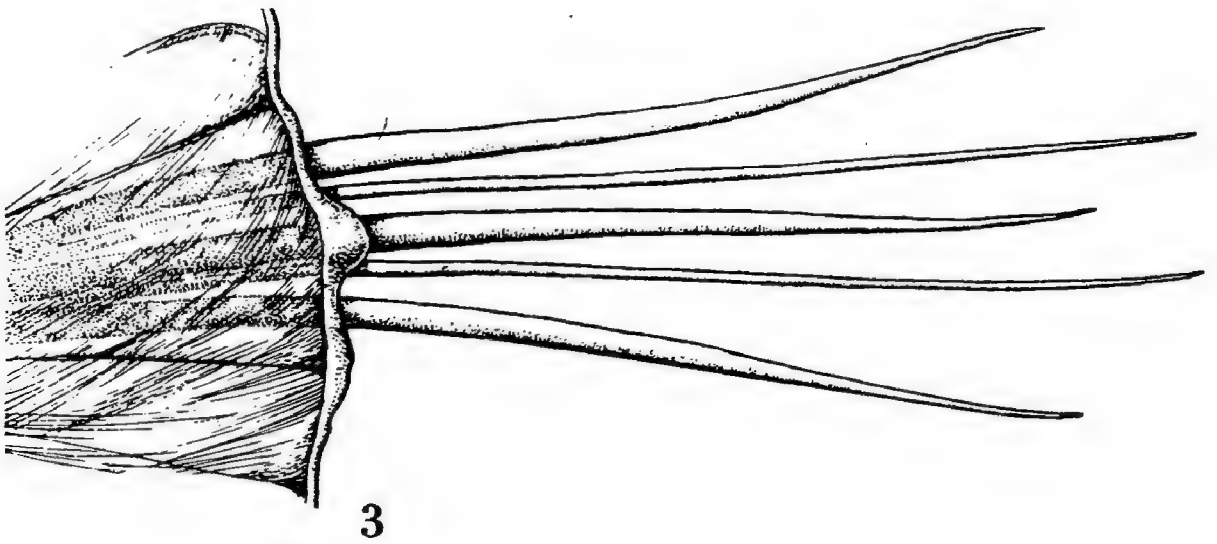
C. hedgpethi is known only from Texas littoral zones.

Family ARENICOLIDAE

A single member of the lug-worms is present.

Arenicola cristata Stimpson, 1856

Arenicola cristata Ashworth, 1912, pp. 105–111, pls. 5, 8, 10, 13; Fauvel, 1927, pp. 163–164, fig. 57; Warren, 1942, p. 45; Hartman, 1945, p. 37; Behre, 1950, p. 13.



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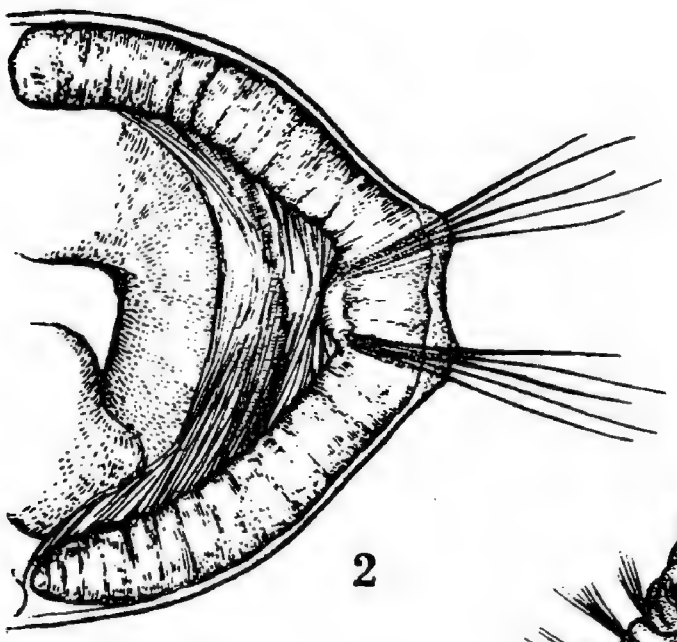

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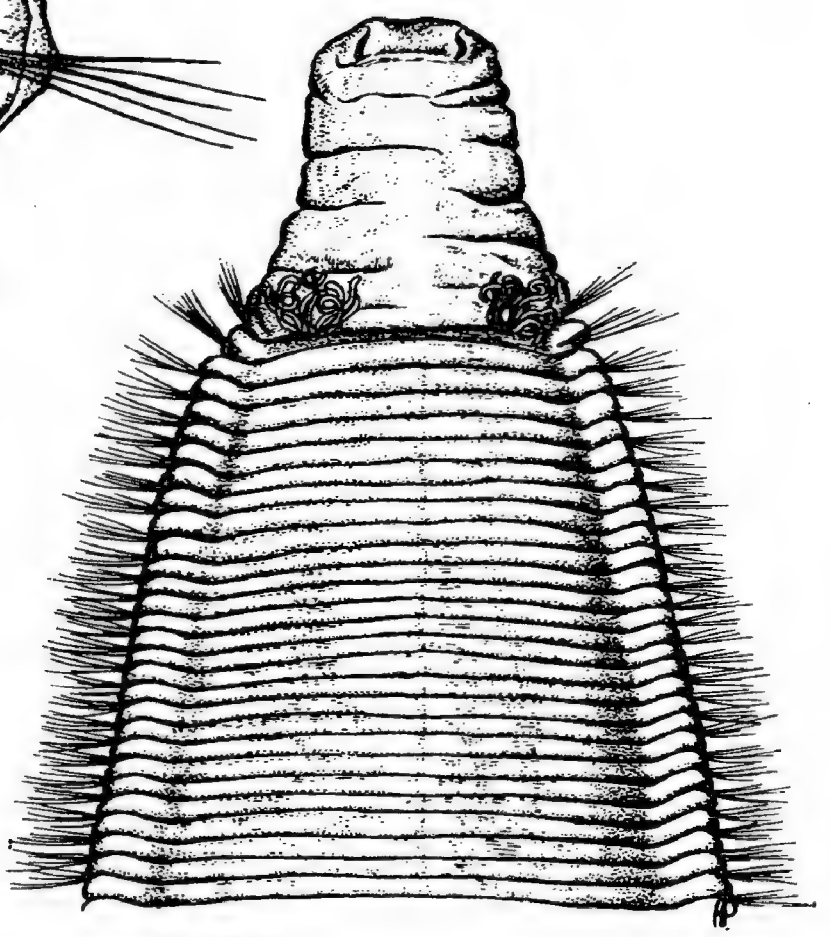

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PLATE 25

FIGS. 1 to 3, *Cirratulus hedgpethi*, n. sp.
FIG. 1, anterior end in dorsal view, x 8.5.
FIG. 2, cross section through a posterior body segment, showing right half, x 16.5.
FIG. 3, neurosetal fascicle from a far posterior segment, x 177.

This occurs in many muddy sand beaches throughout the Gulf of Mexico, at least west to Texas. Its surface mark is a large cinder cone exposed at lowest tide line. The following beaches in the Gulf of Mexico have yielded specimens: Godfrey and Anderson's Creeks near Englewood, Florida, Caminada Beach, Barataria Bay, Grand Isle, Louisiana, near Biloxi, Mississippi from sand flats with oysters, and Wakulla Beach, Wakulla Co., Florida.

The body is thick, large 50 to 100 mm. long or more. There are 17 setigerous segments, 11 pairs of tufted branchial pairs followed by a caudal region which lacks parapodia. The surface epithelium is strongly areolated and its anterior parts are transversely ringed farther back.

Arenicola cristata is otherwise known from limited cosmopolitan areas (see Ashworth, 1912, pp. 105–111, for detailed account).

Family OPHELIIDAE

Only 2 species are recorded though others are doubtless to be found.

Key to Species

1. Body smooth, small, seemingly lacking segmental furrows, resembling a minute Amphioxus with dark segmental patches ..... *Polyophthalmus pictus*
1. Body with segmental cirriform branchiae and lateral segmental eyespots ..... *Armandia agilis*

Armandia agilis (Andrews), 1891

Ophelina agilis Andrews, 1891, p. 289, pl. 15, figs. 21–26, 28.

Armandia agilis Hartman, 1945, p. 37.

Individuals come from Alligator Harbor, Franklin Co., Florida, August, 1950 (coll. D. Carpenter), from Lemon Bay, Florida in sands with *Chaetopterus* and trawled from gravel aggregates.

Length attains 15 to 24 mm., width is 1 mm. or less. The body consists of 36 to 39 setigerous segments. The prostomium is long, acutely pointed, its length about twice its width; it has a pair of large, circular nuchal organs at the sides, just in front of the first parapodia. The mouth on the ventral side, is in line with the first setiger. Lateral eyespots number 20 or 21 pairs; they are black, approximately circular in shape, first present between setiger 6/7 or 7/8 and continued back through setigers 26/27; they are located just in front of the parapodial bases. The anal funnel is long, its length about equal to that of the last 6 setigers; it is transversely barred with light and dark areas, approximately equal to one another and numbering about 20. The posterior end has a very long, midventral cirrus that is about as long as the funnel, and up to 8 shorter processes arranged in a circlet. The alimentary tract contains fine quartz particles.

Armandia agilis is more extensively known from North Carolina; in the Gulf of Mexico it is known only from Florida.

Polyophthalmus pictus (Dujardin), 1839

Polyophthalmus pictus Fauvel, 1927, pp. 137–138, fig. 48; Rioja, 1946, p. 195.

This is recorded from Vercruz, Mexico by Rioja (1946, p. 193). It occurs typically among intertidal algae and rocks. It attains a length of 10 to 20 mm. and is slender, very agile, sometimes highly colored in life, with transverse bars of brown to reddish black. There are 27 or 28 segments.

This is known from both sides of North America in littoral zones, in addition to cosmopolitan areas.

Family FLABELLIGERIDAE

These are the bristle-cage worms, characterized for having tufts of setae directed forward to form a cephalic cage. The surface of the body tends to be roughened due to the presence of epithelial papillae and adherent sand particles. The prostomium and its surrounding parts including the peristomium and its tentacular processes are completely retractile into the oral aperture, and thus visible only by dissection unless these parts are everted by fixing. Two species are here recorded.

Key to Species

1. Peristomium forming a tongue-like process (pl. 26, fig. 1) that extends forward over the prostomium; neuropodial hooks have a bifid tip (pl. 26, fig. 3) ..... *Semiodera roberti*

1. Peristomium without such tongue-like process; neuropodial hooks with entire tip ..... *Stylarioides inflata*

Stylarioides inflata (Treadwell), 1914

Stylarioides inflata Hartman, 1951 (in press, Pacific Science).

This was taken from trawled shell aggregates in Lemon Bay, Sarasota Co., Florida. It occupies a U-shaped burrow in friable rocks or shell masses.

The anterior end is widest and obliquely abrupt (peristomial cirri withdrawn) to form a plaque on the dorsal side of the first 4 segments. The surface of the body is slightly roughened and covered with a very thin layer of minute sand grains. The surface papillation is limited to anterior margins of segments. The prostomium (seen by dissection) is a small lobe with a pair of large, lenticulated eyes. The oral tentacles, inserted on the peristomial base are in crescentic arrangement, surrounding the dorsal margins of the thick and paired palpi and the prostomium. The oral tentacles are numerous, including about 6 larger and 13 smaller on each side.

Setae of the first 2 segments are longer than others and directed forward to encompass the anterior end. Notosetae are fine, distally pointed and transversely barred. Neurosetae of the first 3 segments are distally pointed and resemble the notosetae; thereafter they are thicker, distally blunt, entire and slightly curved along the shaft.

Stylarioides inflata is more widely distributed on the Pacific side of North America, from Oregon to Lower California, Mexico (Hartman, in press).

Semiodera roberti, new species

Plate 26, figs. 1–4

Stylarioides eruca Behre, 1950, p. 14.

This comes from Sugar House Bend, Grand Terre, Louisiana, June 24, 1942 (coll. J. H. Roberts).

A long, posteriorly tapering specimen measures 68 mm. long for 115 segments. It grossly resembles *Stylarioides eruca* (Claparède) because of its similar body proportions and bifid neuropodial hooks (fig. 3). However, the surface epithelium is much less papillated and the oral tentacles are inserted on a tongue-like process (fig. 1) as characteristic of the genus *Semiodera* Chamberlin. The first few parapodial parts are prolonged forward and have longer setae than those farther back; the setae form a distinct cephalic cage.

The oral structures are everted on this individual. The tongue-like process is longer than wide, has a deep median longitudinal furrow and each half is provided, on its ventral side, with a closely spaced series of tentacular bases (fig. 2) from which all tentacles have fallen away (assuming that there were tentacles). This tongue overhangs the comparatively minute prostomial lobe and the palpal bases, from which the palpi have also fallen. The prostomium is a small, triangular lobe with a pair of large eyes at the sides. Each eye has a large dark red circular lens and the embedded parts of the 2 eyes are nearly convergent within the cephalic tissue. The entire prostomial portion is surrounded by a collar-like sheath that closely fits about the eversible structures.

Parapodial parts are not conspicuous except in the first few segments where the lobes are triangular, sand-encrusted and projecting forward (fig. 1). Farther back the notopodia have a linear series of long, pointed setae, a single, slender papilla on the posterior side that extends distally nearly as far as the setae, and several smaller papillae. Neuropodia have linear series of hooks and a few slender papillae in a posterior position. Notosetae are long, slender, distally pointed and transversely barred. Neurohooks are shorter and have a bifid tip (fig. 3) with a few transverse bars along the length. The bifid tip (fig. 4) has a falcate tip and an accessory, flattened process or flap that appears tooth-like only when seen on edge.

Semiodera roberti differs from other species of the genus for the bifid character of the neuropodial hooks. A nearly related species is shown in color by Ehlers (1887, pl. 42, fig. 6) as *Siphonostomum cariboum*. I take pleasure in naming the new one for the finder, Mr. J. H. Roberts.

This is known only from the type locality, Grand Terre, Louisiana.

Family CAPITELLIDAE

The capitellids are small (a few mm. long) to large (80-100 mm. long) usually cylindrical, purplish red annelids in which the body is divisible into thorax and abdomen. The prostomium is a small, plain lobe; the proboscis is a soft, unarmed eversible pouch. Parapodia lack lamellar processes or have segmental branchiae that are eversible or stationary. The several species are often associated with mud of ooze and in some instances form beds. Seven species are recorded.

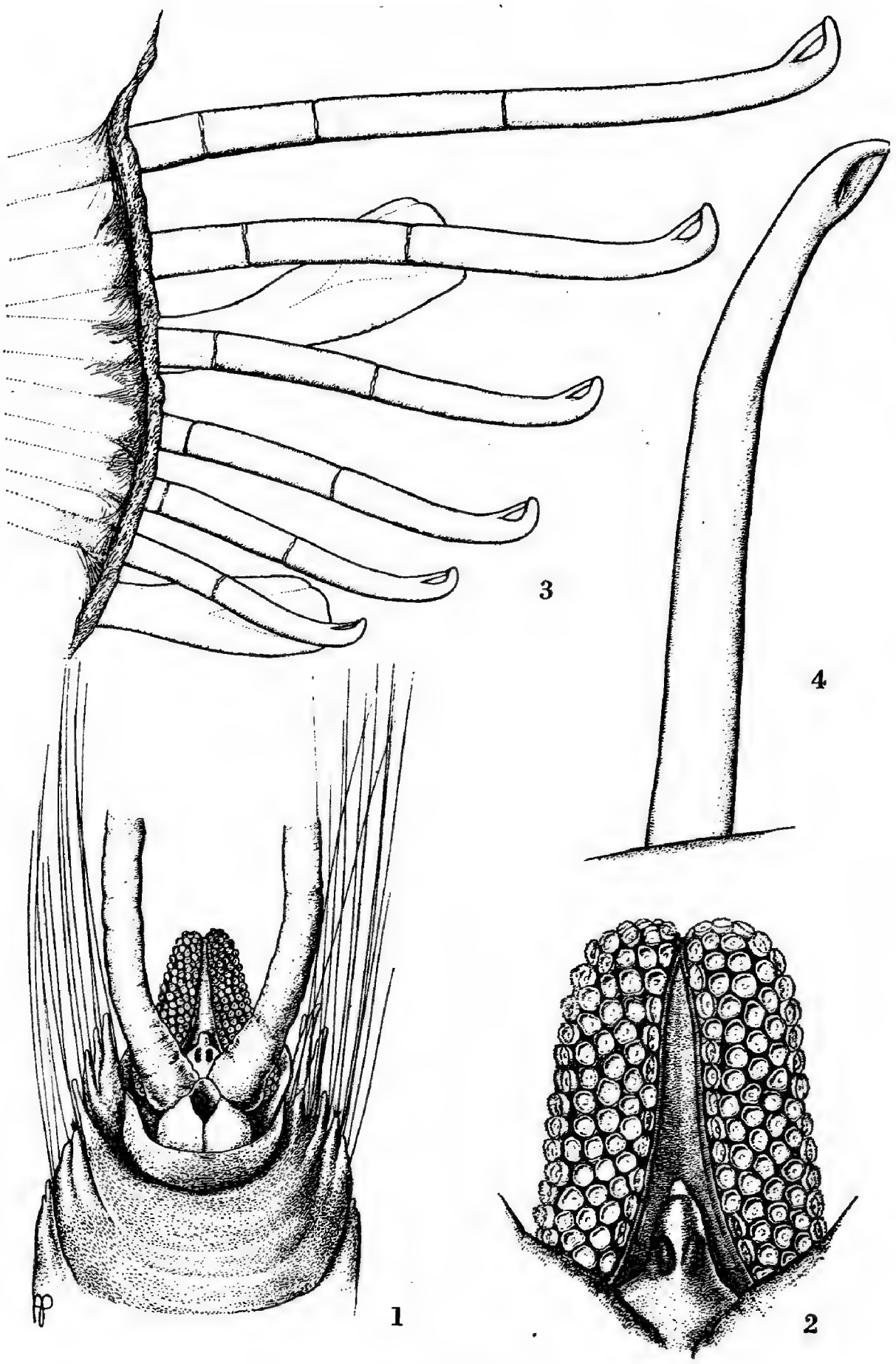


PLATE 26

FIGS. 1 to 4, *Semiodera roberti*, n. sp.

FIG. 1, anterior end in ventral view with prostomium and associated parts everted, x 21.

FIG. 2, prostomium and overhanging tentacular process in ventral view, x 53.

FIG. 3, a neuropodium from a median segment in anterior view, x 221.

FIG. 4, distal end of a neuropodial hook to show broad accessory process, x 445.

Key to Species

1. Thorax consists of 9 segments ..... *Capitella capitata*
1. Thorax consists of 10 segments ..... *?Capitellides teres*
1. Thorax consists of smooth peristomium and 10 setigerous segments ..... *Mediomatus californiensis*
1. Thorax consists of 11 setigerous segments (pl. 24, fig. 1) 2
1. Thorax consists of 13 setigerous segments ..... *Dasybranchus* 4
2. All thoracic segments have pointed setae ..... *Notomastus* 5
2. First 5 thoracic segments have pointed setae, last 6 segments have hooded hooks ..... *Heteromastus filiformis*
3. Prostomium has paired patches of eyespots; first setigerous segment has both notopodia and neuropodia ..... *Notomastus latericeus*
3. Prostomium has a single pair of eyes (pl. 24, fig. 2); first setigerous segment lacks neuropodia (pl. 24, fig. 1) ..... *Notomastus hemipodus*
4. Branchiae occur as single or double filaments from some abdominal segments ..... *Dasybranchus lunulatus*
4. Branchiae occur as bushy tufts emergent from the upper edge of some abdominal neuropodia ..... *Dasybranchus lumbricoides*

?Capitella capitata (Fabricius), 1780

Capitella capitata Fauvel, 1927, pp. 154–155, fig. 55; Hartman, 1947, pp. 402, 404–405.

One small specimen comes from Turtle Bayou, Aransas Bay, Texas, October, 1950 (coll. A. E. Hartman); it was associated with decaying vegetation in fine sand bottom. It measures about 5 mm. long and is nearly complete. The first 7 setigers have pointed setae only, segments 8 and 9 have hooks only; there are no genital hooks, hence the doubtful identification, indicated above.

Capitella capitata is recorded from cosmopolitan regions in littoral zones, especially from lagoons, sloughs or other inlets in mud or mixed bottoms. It has remained unreported in the Gulf of Mexico, but may be recovered from soft muds in vertical burrows.

?Capitellides teres Treadwell, 1939

Capitellides teres Treadwell, 1939, p. 6, figs. 21–24.

The original and only known specimen comes from Port Aransas, Texas. Through the courtesy of the American Museum of Natural History, I have re-examined this specimen. It is posteriorly incomplete, consists of the prostomium and 19 setigerous segments. Large ova are seen in segments 11 and 12; they show through the body wall. The first segment is setigerous, with notopodia and neuropodia. Segments one to 8 have pointed setae above and below; segments 9 and 10 have long handled, hooded hooks. A single large yellow genital spine is visible on the middorsum, between the eighth and ninth segments. There is no sharp separation between thorax and abdomen. There are no visible branchiae on any of the segments.

This specimen resembles a species of *Capitella* (above) since the first segment is setigerous. It resembles the genotype of *Capitellides* Mesnil, *C. giardi* Mesnil, since genital hooks are present in the female. It departs from species of both these genera in that there are no visible hooded hooks in the first 8 setigerous segments. In this respect there is no known genus in the family (see chart of capitellid genera in

Hartman, 1947, p. 402) to define the species. If a new genus is erected for it, its place will be in the group having setae in the first segment and thorax with 10 segments.

Mediomastus californiensis Hartman, 1944

Mediomastus californiensis Hartman, 1947, p. 408, pl. 46, figs. 3, 4.

Five specimens come from Alligator Harbor, Franklin Co., Florida, washed from fine sandy tubes on beach, Jan., 1950 (coll. D. Carpenter). The longest measure 20 mm. long and less than half a mm. across. The first segment is a smooth ring; the thorax includes 4 segments with only pointed setae and 6 successive ones with hooded hooks. The abdomen comprises about 80 segments and ends in a long, digitate cauda on the ventral side of the anal pore. The species is otherwise known from Oregon to California, in intertidal muddy sands.

Heteromastus filiformis (Claparède), 1864

Heteromastus filiformis Fauvel, 1927, pp. 150–152, fig. 53; Hartman, 1947, pp. 402, 427–428.

This is very abundant at the mouth of Godfrey Creek, Lemon Bay, Florida, Jan. 1938; on mud flats at Englewood, Florida; also Bald Point, Ochlockonee Bay, Franklin Co., Florida, March, 1950 (coll. L. M. Henry) and in Turtle Bayou, Aransas Bay, Texas, in fine sand with decaying vegetation, October, 1950 (coll. A. E. Hartman). Others come from Rockport, Texas, in beach at low tide, July, 1946 (coll. J. W. Hedgpeth).

Length is 20–40 mm. but the posterior end is apt to be much coiled. The first segment is smooth and lacks parapodia; the next 5 have setae in both notopodia and neuropodia, the following 6 have long handled hooded hooks above and below; the transition from throax to abdomen is thereafter. Abdominal parapodia are somewhat enlarged and branchial. Color in life is deep maroon; preserved it is much paler.

In most specimens the branchial processes are short vesicles; in some from Texas, however, these processes are conspicuously longer, resembling lobes and they are continued through many abdominal segments.

Heteromastus filiformis is widely known from both sides of North America, from Europe and elsewhere. Its surface mark is a small cone.

Notomastus latericeus Sars, 1851

Notomastus latericeus Fauvel, 1927, p. 143, fig. 49; Hartman, 1947, pp. 402, 411.

Finds come from Alligator Harbor and Bald Point, northwestern Florida, March, 1950 (coll. L. M. Henry). The prostomium has paired patches of eyespots. All thoracic segments have pointed setae only. Anterior abdominal segments have the superior edge of neuropodial ridges prolonged to form branchial lobes. Some other specimens, taken near Beaufort, North Carolina, muddy sand, shore, agree fully with these from the Gulf. Color in life is dark red, preserved it is pale.

This is known more extensively from Europe and other widely scattered geographic areas. It is not yet recorded from the western half of the Gulf of Mexico.

Notomastus (Clistomastus) hemipodus Hartman, 1945

Plate 24, figs. 1–3

Notomastus (Clistomastus) hemipodus Hartman, 1947, pp. 424–426, pl. 48, figs. 1–5.

This comes from Lemon Bay, Sarasota Co., Florida in a sandy shoal, January, 1938. Length is about 30 mm. The prostomium (fig. 2) has a pair of eyespots near the posterior margin. The first segment is smooth or somewhat areolated and lacks setae. The second has notosetae (fig. 1) but no neuropodia. Nephridial apertures, located at the sides in segmental grooves (fig. 1) are limited to posterior thoracic segments. Lateral organs, located between the notopodia and neuropodia, are papillar in the thorax (fig. 1) and eversible pouches (fig. 3) in the abdomen. The proboscis is a large, eversible pouch that is papillated proximally (fig. 1) and smooth, epithelial more distally.

This is known more widely from North Carolina; it is not yet recorded from the western end of the Gulf of Mexico.

Dasybranchus lunulatus Ehlers, 1887

Dasybranchus lunulatus Ehlers, 1887, pp. 174–177, pl. 45, figs. 5–9; Hartman, 1947, pp. 432–434, pl. 56, figs. 1, 2.

Several come from southwestern Florida in sandy mud shoal exposed at low tide, January, 1938. The prostomium has a pair of ocular patches located in front of the nuchal slits. The first segment is smooth; the next 13 have setae in both notopodia and neuropodia. Abdominal segments have long handled hooks only. The epithelium of the thorax is nearly smooth except for a few wrinkles. Some abdominal segments have digitate branchial lobes that are emergent from a small pore at the upper edge of parapodia.

This is known from the Florida Keys and some West Indian regions in addition to North Carolina. It is not yet known from the western end of the Gulf of Mexico.

Dasybranchus lumbricoides Grube, 1878

Dasybranchus lumbricoides Hartman, 1947, pp. 431–432, pl. 56, figs. 3, 4.

Specimens come from Alligator Harbor and Bald Point, Franklin Co., Florida, April and May, 1950 (coll. L. M. Henry).

This is a large, deep bluish red worm that autotomizes readily. Its abdominal segments have bushy branchiae that appear ragged in life. The species is associated in black mud flats and sometimes common. The setal formula resembles that of *D. lunulatus* (above); the 2 species differ in that this has a strongly areolated thoracic region and branchiae are in branched tufts, whereas in *D. lunulatus* the epithelium is nearly smooth and the branchiae are simple lobes.

Dasybranchus lumbricoides is reported from cosmopolitan intertidal seas; it occurs on both sides of North America. It is not yet known to occur in the western part of the Gulf of Mexico.

Family MALDANIDAE

The maldanids, or bamboo-worms, are cylindrical, long jointed annelids that may occur abundantly in some sandy or muddy beaches or in sublittoral depth. They occupy a cylindrical tube which may be thin, friable, covered with a single layer of sand, or thick mud or silt. The anterior or also posterior end of the body is a flattened plaque with or without marginal processes. At least 5 species may be identified.

Key to Species

1. Anal plaque lacks marginal fringe 2
1. Anal plaque has marginal fringe 3
2. Segments 7 to 11 covered with many diffusely arranged slender filaments, appearing pilose ..... *Branchioasychis americana*
2. Without such diffusely arranged filaments ..... *Maldane sarsi*
3. Fourth segment with a deep, membranous collar ..... *Clymenella torquata calida*
3. Fourth segment without a collar 4
4. Body segments number 18 setigerous; anal plaque with alternating long and short filaments ..... *Axiothella mucosa*
4. Body segments number over 30 setigerous; anal plaque with short, uniformly long lobes ..... *?Macroclymene elongata*

Axiothella mucosa (Andrews), 1891

Plate 1, top

Axiothea mucosa Andrews, 1891, pp. 294–295, pl. 16, figs. 29–35.

Axiothella mucosa Hartman, 1945, pp. 38–40, pl. 8, figs. 5–6; Bookhout and Horn, 1949, pp. 145–184, pls. 1–5.

Many specimens come from Wakulla Beach, Wakulla Co. and Bald Point, Franklin Co., Florida, March, 1950 (coll. L. M. Henry). Some of these lots have gelatinous egg masses.

On the cephalic plaque the nuchal organs are straight and extend only about half the length of the plaque. Ocelli are numerous, arranged in 3 conspicuous patches on the under side of the head; one patch is midventral and the other 2 are paired. The body consists of 18 setigerous segments and ends in 3 closely spaced preanal ridges that lack parapodia. The anal plaque has about 32 marginal fringes; one of them, the midventral, is much the longest, 8 others are moderately long and the rest are of varying shorter lengths, alternating with the 8 longer ones. The inner anal cone is closely covered with minute papillar processes. There is no indication of a collar on the fourth or other segment. The first few neuropodia have transverse lineal series of 8 or more hooks in each.

In northwestern Florida this species deposits plum-shaped and sized gelatinous masses with ova from January to March. These masses measure about 41 mm. long and 20 mm. wide and protrude from the distal end of the tube. The latter is sand covered, measures over 70 mm. long and 4 to 5 mm. across at the top; it stands upright in the sand flats and is nearly covered except for its distal end. An exposed bed of this species is shown in pl. 1, top.

Axiothella muçosa is more widely recorded from North Carolina; it is not yet known from the western Gulf of Mexico.

Clymenella torquata calida, new subspecies

Clymenella torquata (Leidy), 1855; Hartman, 1945, p. 40, pl. 8, figs. 1, 2; Newell, 1949, pp. 147–155, figs. 1–8; Behre, 1950, p. 13.

Several specimens come from Barataria Bay, Grand Isle, Louisiana (coll. E. H. Behre). The largest measure about 56 mm. long; the body is uniformly slender. It consists of 18 setigerous segments and 2 apodous preanal ridges. The first 3 segments have uncinial ridges with 9 to 12 hooks in lineal series. The collar on the fourth segment is deep, membranous and continued all around. The cephalic plaque is neatly crenulate at its dorsal edge, with 9 or 10 short lobes; its lateral margins are entire and the ventral edge is a rounded to triangular short lobe. Nuchal organs are straight, nearly parallel to each other; they extend through most of the cephalic length; there are no ocelli.

The anal plaque is fringed at its outer margin; there are about 11 longer, filamentous lobes that alternate nearly regularly with an equal number of short lobes. In the stem species, *C. torquata* (Leidy), there are about 21 subequally short lobes together forming a circlet.

The subspecies, *calida*, differs from the stem species in the following respects: The dorsal edge of the cephalic plaque is crenulate, not entire or only wrinkled; the anal plaque is crenulate at its dorsal edge and provided at its lateral and ventral margins with alternating long and short filaments intead of having uniformly short filaments all around.

The tube is sand covered with uniformly small particles over a thin membranous layer; it is easily broken. An occasional shell fragment is externally attached. The account of Newell (1949, pp. 147–155) concerns the introduction of the stem species at Whitstable, England, where oysters are cultured.

The stem species is originally described from New Jersey and since recorded from New England south to North Carolina. The distributional relations of the species and the subspecies noted above, have not been cleared since the subspecific differences are not yet noted on individuals from different localities.

Branchioasychis americana Hartman, 1945

Branchioasychis americana Hartman, 1945, pp. 40–42, pl. 9, figs. 1–4.

Finds come from southwestern Florida, from near Rockport, Texas on a bell buoy in 4–5 feet, Oct. 1946 (coll. J. W. Hedgpeth) and from Wakulla Beach, Wakulla Co., Florida, Jan. 1950 (coll. L. M. Henry).

Individuals come to be large, about 160 mm. long and consist of 19 setigerous segments. The cephalic plaque and first 3 to 4 segments are pale to red and speckled with black. Branchial filaments are diffusely strewn on segments 6 to 11. This is known only from North Carolina in addition to the localities named above. It occurs in soft black mud.

Maldane sarsi Malmgren, 1866

Maldane sarsi Fauvel, 1927, pp. 197–199, fig. 69; Behre, 1950, p. 13.

Several individuals come from near Grand Isle, Louisiana, sand, and Barataria Bay near Grand Isle, July, 1942 (coll. J. H. Roberts); also Biloxi, Mississippi, sand flats; others are taken off eastern Texas, in 42 and 76 fms., Aug. 23, 1950 and Nov. 27, 1950, trawled at stations 86 and 157 by the M/V OREGON.

In the largest specimens (from 42 fms.) the tube is thick, black mud, about 80 to 100 mm. long and 5 mm. wide, closely fitting over a long, cylindrical worm that is about 1.5 to 2 mm. across. Both cephalic and anal plaques have entire lateral margins. The number of body segments is 19 and there are 2 preanal, apodous rings.

This is a widely distributed, cosmopolitan species, associated with soft, muddy bottoms. The present records are intertidal to 76 fms.

?Macroclymene elongata (Webster), 1879

Praxilla elongata Webster, 1879, pp. 124–125; Webster, 1886, pp. 154–155, pl. 9, figs. 55–61.

A posterior end comes from Deer Island, near Biloxi, Mississippi in sand, Nov. 1943 (coll. M. W. Williams). It is long, cylindrical and tapers going back; it consists of 36 segments. There is a single, preanal apodous segment. The anal plaque has a circlet of about 24 similar short lobes. The anal aperture is at the middle of the plaque; it has a short, thick papilla at its ventral end. The last 14 or more body segments are short, moniliform and have deep segmental furrows.

The large number of segments in this specimen and the single preanal segment are unique features of the genus *Macroclymene* Verrill. Its genotype, *M. producta* (Lewis, 1879) from Massachusetts, is said to consist of about 70 segments; in it there is also an anal plaque with short lobes in a circlet, and posterior segments are short. The present specimen agrees more nearly with what is described as *Praxilla elongata* Webster (1886, p. 154) in which the total number of segments is at least 39. The identity is here questioned since the parts of the cephalic plaque have not been examined.

?Macroclymene elongata (Webster) is first described from New Jersey, and recorded from New England as a species of *Praxillella;* it is here being newly combined as a species of *Macroclymene.*

Family OWENIIDAE

Owenia fusiformis delle Chiaje, 1841

Owenia fusiformis Fauvel, 1927, pp. 203–204, fig. 71.

Collections come from southwestern Florida in old snail shells, and in sandy beaches; others are from Bald Point, Franklin Co., Florida, March, 1950 (coll. L. M. Henry).

The tube measures 70 to 130 mm. long and about 2 mm. wide at its greatest width or near the middle; it tapers slightly to both ends; it is tough and covered on the outside with small sand grains. The animal within measures about 45 mm. long and

consists of 20 segments. The cephalic plaque is surrounded by a serrated membrane. The body is cylindrical, resembling that of the maldanids (above) but the posterior end tapers to a simple pygidium.

This is regarded as cosmopolitan in distribution, occurring especially in low littoral zones. It is not yet known from the western Gulf of Mexico.

Family PECTINARIIDAE

This family comprises the gold-crown worms; the tube is solitary, in the form of a prolonged cone open at both ends, with the widest or head end down and the narrow tail end open at the surface of the sand. A single species is recorded.

Cistenides gouldii Verrill, 1873

Cistenides gouldii Hartman, 1942, p. 74, figs. 130, 135, 138; Hartman, 1945, p. 43; Behre, 1950, p. 13.

There are tubes and specimens from Landry's oyster bed, Grand Isle, Louisiana, July, 1937, and from Lemon Bay, Florida, Jan. 1938; others are from Wakulla Beach, Wakulla Co., Florida, Jan. 1950 (coll. L. M. Henry) and from near Biloxi, Mississippi, May, 1942 (coll. A. E. Hartman).

The tube is delicate, conical and slightly arcuate, covered with a single layer of very fine sand; it measures to 64 mm. long. The cephalic hooks are pale yellow and distally pointed. The scaphal hooks are distally rounded and terminate in a short, lateral boss (Hartman, 1942, fig. 130). The shorter notosetae are sharply incised.

This is elsewhere known from Massachusetts south to the West Indies.

Family SABELLARIIDAE

These opercular, gregarious annelids construct thickly concreted tubes which are apt to be massed and may be reef-like. Two species are known.

Key to Species

1. Middle paleae of opercular crown alternate long and short ..... *Sabellaria floridensis*
1. Middle paleae of opercular crown uniform in size ..... *Sabellaria vulgaris beaufortensis*

Sabellaria floridensis Hartman, 1944

Sabellaria floridensis Hartman, 1944, pp. 345–346, pl. 31, figs. 37–41; Rioja, 1946, pp. 196–198, figs. 2–8.

This occurs in Lemon Bay, Sarasota Co., Florida; others come from Alligator Harbor, Franklin Co., Florida, July, 1950 (coll. L. M. Henry); it is recorded also from Tecolutla, Mexico by Rioja (1946).

The opercular crown has 3 apparent circular rows of paleae; the outer row are spatulate, with a prolonged, greatly serrated free tip. The middle series alternate long and short, and the inner series are wedge-shaped and have minute serrations at the tip.

This may occur commonly in the Gulf of Mexico in its northern and western fringes; its most northward occurrence is off New River, North Carolina, taken June, 1949 (coll. A. S. Pearse).

Sabellaria vulgaris beaufortensis Hartman, 1944

Sabellaria vulgaris beaufortensis Hartman, 1944, p. 342, pl. 32, figs. 45–47; Hartman, 1945, p. 43; Rioja, 1946, pp. 195–196, fig. 1.

This is recorded from Tecolutla, Mexico by Rioja (1946). The species is elsewhere known only from Beaufort, North Carolina in a depth of 60 feet.

Family AMPHARETIDAE

Key to Species

1. With a serrated transverse membrane (pl. 27, fig. 1) behind the branchial bases; a pair of large dorsal hooks in front of the branchial bases ..... *Melinna maculata*
1. Without such serrated membrane behind the branchiae; without heavy dorsal hooks ..... *Amphicteis gunneri floridus*, new subspecies

Melinna maculata Webster, 1879

Plate 27, figs. 1, 2

Melinna maculata Webster, 1879, pp. 261–262, pl. 10, figs. 145–147.

Melinna cristata Hartman, 1945, pp. 43–44; Behre, 1950, p. 13. *Not* Sars, 1856.

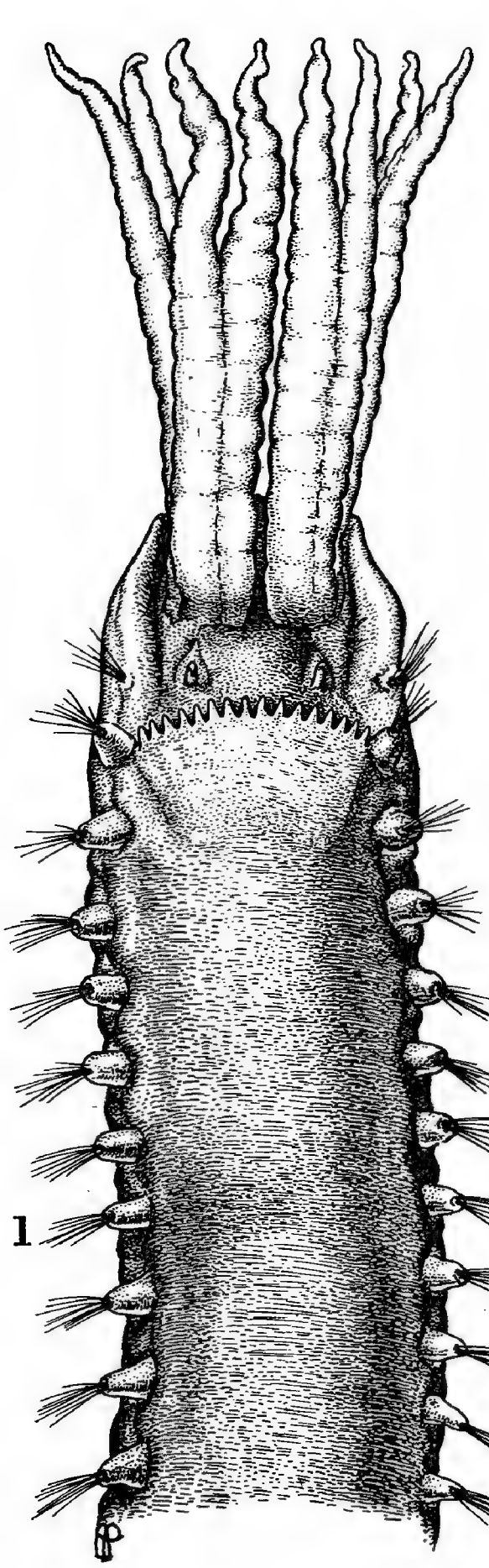
There are finds from Grand Isle, Louisiana (coll. E. H. Behre) and from near the same locality near Sugar House Bend, mud bottom, Aug. 1948 (coll. J. H. Roberts). Two others are from Alligator Harbor, Franklin Co., Florida, March, 1951 (coll. D. Carpenter).

This species has remained briefly known through its original account based on material from Virginia.

A specimen not quite complete in back measures 18 mm. long, consists of 18 thoracic and 22 abdominal setigerous segments. The prostomium is 3-lobed with the middle lobe secondarily incised so as to appear 4-lobed. The thoracic membrane, behind the the branchiae is deeply pouched and its anterior margin has 12 to 14 serrations (fig. 1). The oral tentacles are numerous, slender, filiform, smooth and all of one kind. The single large hooks on the dorsum, in front of the branchial bases, are dark brown and transversely striated. Branchiae number 4 pairs; they are arranged in 2 groups, those of each group fused for a considerable distance (figs. 1, 2); in addition, the narrow transverse white bands are visible (preserved) as originally described by Webster (1879, p. 261).

In life the color of the body is flesh, with green tinge and flake-white specks on the anterior dorsum; branchiae are green with red center and have narrow white transverse bands (Webster, 1879).

Melinna maculata is further known from Virginia; specimens which I (1945, p. 43) reported as *M. cristata* from North Carolina also belong here. It was reported questionably also from St. Thomas, West Indies in 390 and 470 fms. by McIntosh (1885,



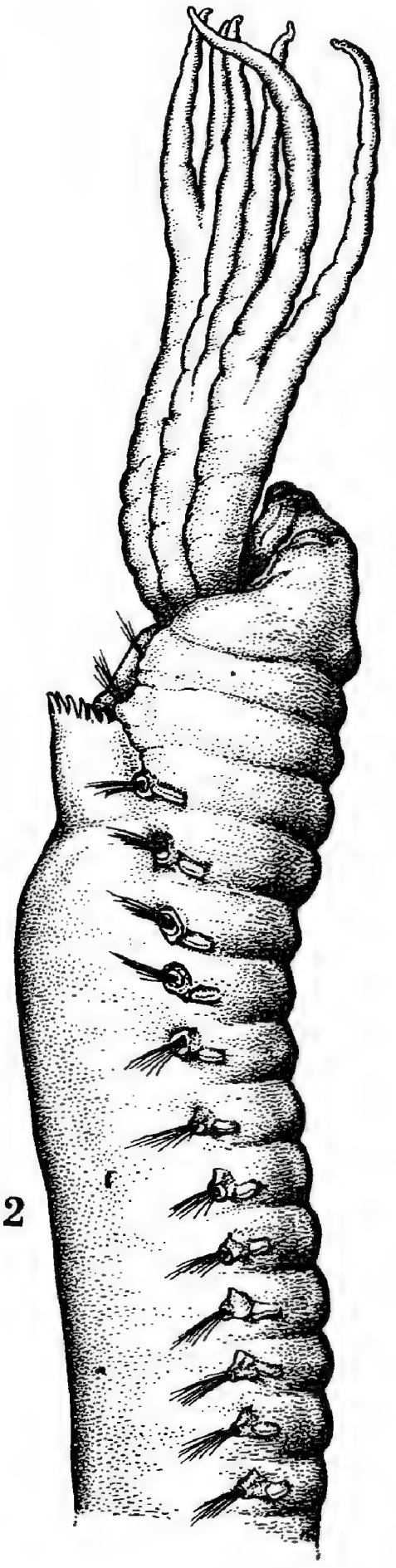


PLATE 27

FIGS. 1, 2, *Melinna maculata* Webster.
FIG. 1, anterior end in dorsal view, x 18.
FIG. 2, anterior end in right lateral view, x 18.

p. 438). The nearly related *M. cristata* (Sars) occurs in colder seas including northeastern United States.

Amphicteis gunneri floridus, new subspecies

Amphicteis gunneri Fauvel, 1927, p. 231, fig. 80.

Five individuals from near Englewood, Florida, in intertidal muddy sands at the lower end of Godfrey Creek where it empties into Lemon Bay, were taken Jan. 1938; seven others come from Ocklockonee Bay, Florida, March, 1951 (coll. D. Carpenter).

Length attains 30 mm., width is to 1.7 mm. at the fifth setiger or widest part of the body. It tapers toward a slender posterior end to a large, terminal anal pore. The prostomium is prolonged forward as a broad snout, has a pair of longitudinal glandular ridges and one pair of black eyespots at the postectal ends of the ridges. There are 4 pairs of thick, smooth, tapering branchiae that lack a connecting membrane; the 8 pairs are separated from each other by a narrow space. They are inserted in 2 transverse rows.

Paleal spines are present in front of the branchial bases; they number 8 to 10 on a side, are long, slender, pale yellow and arranged in a fan-shaped fascicle on each side. Farther back there are 17 thoracic segments and 28 abdominal ones, the number of segments thus totalling 56, which is considerably higher than is typical of *A. gunneri* (Sars). The latter has about 15 instead of 28 abdominal segments.

The oral tentacles, everted on one specimen, are smooth, long, cylindrical. Thoracic notopodia have a papillar cirrus at the distal end, below the setal row (see Fauvel, 1927, fig. 80d); abdominal neuropodia have longer cirri. The tube is thin, membranous, externally covered with a layer of fine sand and at its distal, broadest end it has, in addition, some irregularly attached small bivalve shells. The tube is more than twice as long as the worm within.

The stem species, *Amphicteis gunneri* (Sars) is widely known from colder waters; it may attain a greater size but has fewer abdominal segments; prostomial eyes are in paired patches. *Amphicteis procera* Ehlers (1887, p. 226) off southern Florida in 339 fms., is another species; its branchial bases are widely separated and it has to 50 paleae on a side.

Family TEREBELLIDAE

These are tubicolous, soft bodied, richly tentacled worms which may attain large size and be abundantly present in some areas. Eight species in 6 genera are here reported, but others are doubtless to be found.

Key to Species

1. Branchiae a single pair, each one with a thick base and 4 pectinately divided branches ..... *Terebellides stroemi*
1. Branchiae otherwise and more numerous 2
2. Branchial processes present on many segments, each with a long filament ending in a tuft of fine setae ..... *Enoplobranchus sanguineus*
2. Branchial processes present on 3 or fewer segments and lacking distal setal tufts.... 3
3. Thorax with 3 pairs of branchiae 4
3. Thorax with 2 pairs of branchiae 7

4. Anterior end of thorax with lateral lappets; thoracic segments include 17 that are setigerous 6
4. Anterior end of thorax without lateral lappets; thoracic segments number more than 24 5
5. Branchiae are richly branched dendritically with the third or last pair much the smallest ..... *Terebella rubra*
5. Branchiae are arranged in 3 pairs of filamentous tufts that resemble one another ..... *Thelepus setosus*
6. Thoracic hooks have 6 to 8 teeth; tubes of fine sand or mud ..... *Loimia viridis*
6. Thoracic hooks have 5 or 4 teeth; tube coarse, externally covered with fragments and bits of debris ..... *Loimia medusa*
7. The 2 pairs of branchiae on long, cylindrical stalks, each with a compact tuft of filament at distal end ..... *Pista cristata*
7. The 2 pairs of branchiae dendritically branched, not compact ..... *Pista palmata*

Loimia viridis Moore, 1903

Loimia viridis Moore, 1903, pp. 723–724, figs. 11–14; Hartman, 1945, p. 46, pl. 10, figs. 4, 5.

Collections come from near Biloxi, Mississippi, muddy sand flats with oysters, Dec. 1943 (coll. M. W. Williams); others are from Alligator Harbor, Franklin Co., Florida, Oct. 1950 (coll. L. M. Henry and D. Carpenter).

The tubes are fragile, uniformly covered with fine sand or thin to thick mud; the tube is cylindrical to collapsed (when the walls are thin). On the body the tentacles are pale or at least not checkered; otherwise the body shows pigment patterns on the thoracic ventrum, as in *L. medusa* (below).

The dorsum is strongly arched and smooth in the region of the thorax. This contrasts with species of *Pista* where the dorsolateral margins are elevated. Branchiae, numbering 3 pairs, are unequal in size, the first much larger than the others. The first pair of lateral lappets is fused across the ventrum; the second pair is lateral and located on the second branchial segment. There are 17 thoracic setigers. Thoracic and abdominal uncini have 6 to 8 teeth in a single or pectinate row. In most terebellids the uncini have teeth arranged in a crown to resemble a beak.

A commensal crab is to be found in tubes from Mississippi. The species is more extensively known from Woods Hole, Massachusetts and North Carolina.

Loima medusa (Savigny), 1818

Loima turgida Andrews, 1891, p. 298, figs. 46–49; Hartman, 1945, p. 46, pl. 10, figs. 2, 3.

More than 50 specimens come from near Englewood, trawled from the Pass in a few feet of water from bottom of oyster aggregates, also from Grove City Key in a shallow channel leading from the Gulf side of Thornton Island, attached to a large rock covered at low tide. Others are from near Biloxi, Mississippi from muddy sand flats in oyster associations, Dec. 1943 (coll. M. W. Williams).

In all the tube is well chitinized and externally covered with bits of debris, shell fragments and other material. A commensal crab occurs in the tube of some specimens. The dorsum is smooth, arched, and shows segmental furrows only obscurely. There are 3 pairs of dendritically branched branchiae. There are 2 pairs of lateral lappets,

the first larger and continuous across the midventrum; the second pair is lateral, just as in *Loimia viridis* (above). The tentacles are crossed by a checkered pattern, with dark and light transverse areas. Thoracic hooks are pectinate and have 4 or 5 teeth in single series.

Loimia medusa is widely recorded from tropical and subtropical localities in cosmopolitan seas. Its tubes sometimes occur in considerable number, buried vertically in sandy mud and gravel beaches exposed at low water line.

Terebella rubra (Verrill), 1873

Leprea rubra Verrill, 1873, pp. 615–616.

Terebella rubra Hartman, 1945, p. 44.

More than 20 specimens come from southwestern Florida near Englewood; some are from old snail shells, others were trawled from oyster aggregates in a few feet and others from holes in large rocks pulled up from littoral zones.

In life the body is uniformly deep red and tentacles are white or at least paler than the body. Length seldom attains 30 mm. Thoracic setae are continued back through a large number of segments, to near the end of the body. Branchiae number 3 pairs, are richly branched; the first pair is the largest. Thoracic notosetae are distally finely serrated; thoracic uncini are avicular, have a large fang surmounted by many small denticles.

The specific name, *rubra*, is used in Linnaeus 13th edition, Systema Naturae (1788). I have retained it here for the American species since the first is not retained in the list of valid species. The same objection can be directed against Risso's name (1826) which is retained for the species now named *Amphitrite rubra* (Risso).

Terebella rubra is further recorded from New England to North Carolina (Hartman, 1945, p. 44).

Pista palmata (Verrill), 1873

Scionopsis palmata Verrill, 1873, pl. 11, fig. 3.

Pista palmata Behre, 1950, p. 13.

Two individuals come from Thornton Island, near Englewood, Florida, from a large rock at low water, Jan. 1938; others are from Grand Isle, Louisiana among oyster clumps, June and July, 1942 (coll. J. H. Roberts) and from St. Marks Light, Wakulla Co., Florida, from limestone outcropping, Oct. 1950 (coll. D. Carpenter).

Length (preserved) is to 70 mm. The body is pale except for a dark reddish brown triangular spot on the ventrum of segments 9 to 13 and a dark area on the dorsum of the thorax in the region of the blood sinus. The first pair of lateral lappets is much the larger and the second pair is continued dorsally so that the 2 of a pair meet middorsally and have a pair of digitate lobes that are separated from each other medially by a short space. The 2 pairs of branchiae are richly branched dendritically and have a short basal stalk. Thoracic hooks of the first few segments are long handled; farther back the stem is shorter to absent. The tube is thick, gray and has scattered fragments of shells on the outside.

The species is elsewhere known from Massachusetts to New Jersey and Virginia.

Pista cristata (Müller), 1776

Pista cristata Fauvel, 1927, p. 266, fig. 93; Rioja, 1945, p. 198.

This is recorded from Veracruz and Tecolutla, Mexico by Rioja (1946).

The species is easily distinguished for having 2 pairs of long stemmed branchial pairs with thick, bushy distal end. The anterior lateral lappets are present on 3 segments with those of the middle pair the largest. The setal characters resemble those of *P. palmata* (above).

This is known from cosmopolitan areas in subintertidal to deep seas.

Enoplobranchus sanguineus Verrill, 1873

Enoplobranchus sanguineus Hartman, 1944, pl. 54, fig. 8; Hartman, 1945, p. 47.

One comes from Thornton Island, Sarasota Co., Florida on ooze bottom, Jan. 1938. The palmately arranged branchial lobes are continued on many thoracic segments and have slender tufts of fine setae at the tips. These characters are unique among the terebellids. Other parapodial parts are obscure.

This is known elsewhere from New England south to Florida and Bermuda; it is not yet known from the western part of the Gulf of Mexico.

Thelepus setosus (Quatrefages), 1866

Thelepus setosus Fauvel, 1927, p. 273, fig. 95; Monro, 1933, p. 266; Rioja, 1946, p. 198; Behre, 1950, p. 13.

Many individuals come from various parts of the Gulf of Mexico in its northern and western ends, including southwestern Florida, in littoral gravel or oyster bottoms, Grand Isle, Louisiana and Port Isabel, Texas, associated with oysters and aggregated clumps (coll. J. W. Hedgpeth).

Length of individuals exceeds 100 mm. in some. The anterior end behind the tentacular tangle, has 3 pairs of branchial filaments that arise as many filaments. There are no lateral lappets. Thoracic segments are numerous, with more than 20 having notosetal fascicles. The peristomial ridge behind the tentacular base has many minute dark eyespots.

The tube is chitinized, externally covered with shell and debris fragments; it appears untidy. Within there are occasional commensals, including species of polynoids of the genera *Halosydna* and *Lepidametria* or also commensal pinnotherid crabs.

The species is widely recorded from circummundane, warm seas in both hemispheres.

Terebellides stroemi Sars, 1835

Terrebellides stroemi Fauvel, 1927, pp. 291–292, fig. 100; Monro, 1933, p. 266; Rioja, 1946, p. 198.

This is recorded from the Gulf of Mexico at Villa del Mar, Veracruz, Mexico by Rioja (1946) and from the Florida Keys by Monro (1933). It is reported from cosmopolitan seas, especially in subintertidal depths.

Family SABELLIDAE

These, together with the SERPULIDAE (below) comprise the featherduster worms. The thoracic membrane is greatly modified at its anterior end to form a tentacular crown in which the separate branches or radioles are laterally provided with branches or pinnae. The radiolar branches may have ocular spots in single or double series or they may be wanting. The species of one genus *(Branchiomma)* have accessory outer filaments in pairs. The tube is sandy, membranous or parchment-like. Ten species in 7 genera are reported.

Key to Species

1. Tentacular radioles have paired processes on outer sides; body conspicuously speckled with dark and paired spots between parapodial bases ..... *Branchiomma* 8
1. Tentacular radioles lack paired processes along outer sides 2
2. Tentacular radioles, including dorsalmost or also others, have compound eyes at distal ends ..... *Megalomma* 9
2. Without compound eyes at distal ends of tentacular radioles 3
3. Setae of first setigerous segment in paired oblique series ..... *Hypsicomus elegans*
3. Setae of first setigerous segment in a rounded tuft 4
4. Tentacular radioles united by a palmate membrane from base to a middle region of crown ..... *Chone duneri*
4. Tentacular radioles not united by a palmate membrane 5
5. Abdomen with few (about 3) segments ..... *Fabricia*, sp.
5. Abdomen with many (more than 8) segments 6
6. Tentacular radioles have paired eyespots 7
6. Tentacular radioles without paired spots; large, over 100 mm. long when adult; tentacular crown brilliantly colored with transverse bars of light and dark ..... *Sabellastarte magnifica*
7. Tentacular radioles have eyes regularly paired and widely spaced from one another ..... *Sabella melanostigma*
7. Tentacular radioles have very numerous and irregularly distributed eyes throughout ..... *Sabella microphthalma*
8. Outer tentacular processes uniformly short ..... *Branchiomma nigromaculata*
8. Outer tentacular processes alternating long and short ..... *Branchiomma bairdi*
9. Tentacular crown has a single pair of eyes located at distal ends of dorsalmost radioles; thoracic collar oblique, longest ventrally and leaving a broad middorsal space exposed ..... *Megalomma bioculatum*
9. Tentacular crown with many eyes on distal ends of radioles; thoracic collar not oblique and continued dorsally, leaving little space exposed ..... *Megalomma lobiferum*

Branchiomma nigromaculata (Baird), 1865

Dasychone conspersa Ehlers, 1887, pp. 266–270, pl. 54, figs. 1–6; Mullin, 1923, pp. 50–51, pl. 7, figs. 1, 2, 6.

Branchiomma nigromaculata Hartman, 1945, p. 51.

Three specimens come from Fort Pierce Inlet, St. Lucia Co., Florida (east coast), Aug. 1950 (coll. D. Carpenter), 8 others are from Sarasota Co., Florida, Jan. 1938, from large rock at low water line.

The largest measures about 30 mm. long. The tentacular crown is full, spreading and conspicuously marked. The 21 pairs of radioles are about equally long, their

length about half that of the rest of the body. The inner paired filaments of the radioles are in close series; the outer sides of the radioles have black eyespots that alternate regularly with the paired outer processes. There are 8 thoracic and 50 or more abdominal setigerous segments. Dark circular spots occur regularly on all parapodia, between notopodia and neuropodia. Dorsal and ventral sides of the body are much speckled with dots and dashes of dark pigment, irregularly dispersed.

This is fairly common in shallow seas of the West Indies, the Bahamas and south to Brazil; also eastern and western shores of Florida; not yet known from western half of the Gulf of Mexico.

Branchiomma bairdi (McIntosh), 1885

Dasychone bairdi McIntosh, 1885, pp. 495–497, pl. 30a, figs. 13–15, pl. 38a, figs. 5, 6, pl. 39a, figs. 2, 9; Augener, 1922, p. 49; Monro, 1933, p. 267.

This is recorded from Dry Tortugas, Florida by Monro (1933).

Specimens measure about 10 mm. long for the body and another 5 mm. long for the tentacular radioles. The distal ends of radioles are not expanded, as originally shown, but cirriform, according to Monro. Its relation to *B. nigromaculata* (above) is thus nearer than first assumed.

This is typically a West Indian species, known also from Bermuda; it is not yet recorded from the western part of the Gulf of Mexico.

Megalomma bioculatum (Ehlers), 1887

Branchiomma bioculatum Ehlers, 1887, pp. 260–263, pl. 53, figs. 1–9.

Megalomma bioculatum Rioja, 1946, p. 199.

This is recorded from Veracruz, Mexico by Rioja (1946). Length of the body attains about 73 mm. The tube is cylindrical and externally covered with uniformly small shell and gravel bits.

This was originally described off Florida in 91–110 fms.

Megalomma lobiferum (Ehlers), 1887

Branchiomma lobiferum Ehlers, 1887, pp. 254–259, pl. 53, figs. 10–15.

Several finds come from Thornton Island, Sarasota Co., Florida, Jan. 1938, from large rock below low water line. Length of body is about 56 mm. The tube is cylindrical, externally covered with silt and mud and very few coarse materials. In life the anterior end is deep maroon.

This comes originally from Key West, Florida in 1–2 fms. It is not yet known from the western Gulf of Mexico.

Hypsicomus elegans (Webster), 1884

Protulides elegans Webster, 1884, pp. 325–326, pl. 11, figs. 63–74.

Hypsicomus circumspiciens Ehlers, 1887, pp. 271–277, pl. 55, figs. 5–13, pl. 56, figs. 1–3; Rioja, 1946, p. 199.

Sabella alba Treadwell, 1917, pp. 266–267, pl. 3 figs. 10–15.

Parasabella sulfurea Treadwell, 1917, p. 267, pl. 3, figs. 30–33.

Hypsicomus purpureus Treadwell, 1924, pp. 20–21, figs. 30–33.

Hypsicomus phaeotaenia Monro, 1933, p. 267.

Three lots come from Sarasota Co., Florida, from large rock at low water, at Grove city key and trawled in shallow water in a *Molgula-Styela* bed; 5 others are from Franklin Co., Florida, May, 1951 (coll. D. Carpenter); it is recorded from Veracruz, Mexico by Rioja (1946); as *H. circumspiciens* Ehlers it comes from Carysfoot Reef, Florida in 35 fms.

The tube is dark, tough, cartilaginous, sometimes very long and penetrates clumps of calcareous shells or rocks; it is often difficult to remove because of its tortuous windings. In life the body is dark purple. The oblique thoracic setal fascicle readily distinguishes this from other sabellids with which it may occur.

Originally described from Bermuda, this appears to be common throughout southeastern United States in rocky or reefy habitats. It has been regarded the same as *Hypsicomus torquatus* (Grube, 1878) from West Africa. The synonymy is not yet definitely established.

Sabellastarte magnifica (Shaw), 1800

Tubularia magnifica Shaw, 1800, pp. 228–229, pl. 9, figs. 1–6.

Bispira melania Mullin, 1923, pp. 52–57, pls. 1 to 4.

Sabellastarte magnifica Augener, 1922, p. 48.

Sabellastarte indica Rioja, 1946, pp. 198–199.

This typically West Indian species is recorded from eastern Mexico by Augener (1922) and at Veracruz by Rioja (1946). It is well illustrated by numerous photographs in massed tubes and singly by Mullin (1923).

This is the most strikingly colored of the West Indian feather-duster annelids.

The tentacular filaments have a spread of 8 to 10 inches. They are beautifully colored in shades of brown with several series of color spots forming bands, the color combinations being fuscous brown banded with light tan spots, chocolate brown banded with white, dark purple with brown spots, and dark mahogany red banded with light brown. A few are almost white with indistinct barring like watered silk (taken from Mullin, 1923). The length of the body is about 120 mm. of which 90 mm. is tentacular crown.

The species is widely recorded from circumtropical littoral seas. Its specific distinction from the Indo-Pacific *Sabellastarte indica* Savigny is doubtful.

Sabella melanostigma Schmarda, 1861

Sabella melanostigma Schmarda, 1861, p. 36, figs; Ehlers, 1887, pp. 263–266; Monro, 1933, p. 267.

There are collections from Alligator Harbor, Franklin Co., Florida, July, 1950 (coll. L. M. Henry) and others come from Sarasota Co., Florida, Jan. 1938. The tentacular radioles have a few dark red bands with paired black eyespots. The tube is covered with fine silt and mud over a thin, membranous layer.

The species is more extensively known from the West Indies, Bermuda and the Caribbean Sea. It is not yet known from the western Gulf of Mexico.

Sabella microphthalma Verrill, 1873

Sabella microphthalma Hartman, 1945, p. 47.

Several come from Alligator Harbor, Franklin Co., Florida, July, 1950 (coll. L. M. Henry) and from between Rockport and St. Joseph Island, Texas on oyster reefs, Oct. 1950 (coll. A. E. Hartman).

In life the body is pale, 15 to 30 mm. long. The tentacular crown has many minute, irregularly arranged paired eyespots throughout the radiolar length.

The species is known more widely from New England southward, and into the Gulf of Mexico.

Chone duneri Malmgren, 1867

Chone duneri Fauvel, 1927, pp. 336–337, fig. 117.

Two individuals come from clean sandy beach, Thornton Island, Sarasota Co., Florida, Jan. 1938.

The longest measures about 25 mm. of which about 4 mm. is crown. There is no pigment and there are no eyespots. The body consists of 8 thoracic and about 50 abdominal setigerous segments. On the tentacular crown the radioles are united for a great length by a palmate membrane; this extends distally to the free end of the radioles; the latter are long, about equal to a fourth of the radiolar length.

The thoracic collar is large, entire all around, has a deep dorsal notch where it is also lowest and is continued obliquely midventrally where it is longest. The margin is entire. The dorsal bases of the crown are united by a thin membrane that is distally prolonged as a median filament.

This has been recorded from New England and is known from north, west and southern Europe.

Fabricia, sp.

An individual was removed from a collection of *Axiothella mucosa* (above) taken at Bald Point, Franklin Co., Florida, March 1950 (coll. L. M. Henry).

It measures 4.8 mm. long including the tentacular crown which is 0.8 mm. long, and 0.3 mm. wide at most. The body consists of crown, 8 thoracic and 3 abdominal setigerous segments and terminates in a pygidial flap with a pair of dark eyespots at the sides. There is a pair of dark eyespots in the peristomial ring, within the collar base. The body is pale except for the first ventral shield which is dusky and the same is continued less intensely around the same segment. There are 3 pairs of radioles, each with many paired filaments in pectinate arrangement. The paired palpi are long, filamentous, extend distally nearly as far as the radioles. The base of the tentacular crown, at the sides, shows a pair of dark spots, marking the position of the branchial vesicles.

The thoracic collar is best developed at its ventral ends; here it consists of a pair of rounded flaps that are clearly separable at the midventrum. On the dorsal side there is only a small, middorsal lobe, a short distance behind it is a deep, longitudinal depression.

Fabricia sabella (Ehrenberg) has been reported from northeastern United States in addition to other widely dispersed geographic areas. The present specimen differs from *F. sabella* in having well developed collar lobes on the ventral side. I know of no species in which these ventral lobes are paired. Additional collections from the Gulf of Mexico may reveal the presence of an undescribed species of the genus. It is to be sought especially in the superficial layers of sand and mud in low intertidal zones, where there is little shifting.

Family SERPULIDAE

The serpulids are not well represented in the collections available for study. Twelve species in 8 genera are recorded.

Key to Species

1. Tube spiraled, small ..... Spirorbinae ..... *Dexiospira* 7
1. Tube not spiraled and larger ..... Serpulinae 2
2. Lacking an operculum 3
2. With one or two opercula 4
3. Smaller to tiny; tubes in clumps or forming lacy clusters on under sides of stones; intertidal ..... *Salmacina dysteri*
3. Larger, tubes solitary, subintertidal ..... *Protula tubularia*
4. Operculum with a soft or fleshy crenulated disk terminating distally in a circlet of hard spinelike processes ..... *Eupomatus* 8
4. Opercumum without such spinous processes distally 5
5. Operculum with a flange or other fleshy processes at the base of the distal expansion ..... *Pomatoceros* 10
5. Operculum without a fleshy expansion at the base of the distal expansion 6
6. Tubes longitudinally ridged; marine ..... *Vermiliopsis* 11
6. Tubes smooth; aestuarine ..... *Mercierellopsis prietoi*
7. Tube with 3 longitudinal ridges; aperture dextral; attached to Sargassum and other algae ..... *Dexiospira corrugatus*
7. Tube smooth, without longitudinal ridges; aperture dextral; attached to seaweeds, rocks, etc. ..... *Dexiospira spirillum*
8. Distal opercular processes directed inward toward the center 9
8. Distal opercular processes directed outward ..... *Eupomatus protulicola*
9. Distal opercular processes smooth, tapering ..... *Eupomatus dianthus*
9. Some opercular processes with lateral spines about halfway down, on inner side; outer side somewhat geniculate about halfway down ..... *Eupomatus sanctae crucis*
10. Buccal segment with setal fascicle ..... *Pomatoceros minutus*
10. Buccal segment without setal fascicle ..... *Pomatoceros (Pomatoleios) caerulescens*
11. Operculum distally flat ..... *Vermiliopsis annulata*
11. Operculum distally pointed, conical ..... *Vermiliopsis bermudensis*

Eupomatus dianthus (Verrill), 1873

?Eupomatus decorus Treadwell, 1931, pp. 4–5, fig. 3; Behre, 1950, p. 13.

Eupomatus dianthus Hartman, 1945, p. 48, pl. 10, fig. 1; Hedgpeth, 1950, p. 75; Behre, 1950, p. 14.

There are numerous individuals from various parts of the intertidal zone in the Gulf of Mexico from southwestern Florida, in old snail shell and on submerged rocks, from Grand Isle, Louisiana (coll. J. H. Roberts), from south Texas (coll. J. W. Hedgpeth and others). In all instances they are represented by tubes that are fully

attached to a substratum, with the tube somewhat sinuous, weakly longitudinally ridged along part of its length, and with a circular aperture. Total length of expanded individuals is 15 to 25 mm. The operculum has a lower disk of 30 to 36 sharply pointed processes of which the ventralmost are longest and there is gradual decrease in length dorsally. The distal circlet of hard spines includes 10 to 12; these are long, smooth, sharply falcate at the tip, with the pointed ends directed inward; the longest spines are dorsalmost, the shortest at the midventral end.

I have seen no specimens from calcareous tube clumps which are said to occur as fouling masses on the bottoms of boats, as illustrated in plate 3, top. In these the tubes are more or less erect and heavily massed. These tubes may represent another species, or possibly *Hydroides*.

Eupomatus decorus Treadwell (1931) from Grand Isle, Louisiana, is here questionably referred to *E. dianthus*, since it agrees in most details with the other specimens I have regarded as *E. dianthus*. *E. decorus* is said to have a tube that has marked longitudinal ridges; in *E. dianthus* the ridges are not marked.

Eupomatus dianthus (Verrill) is known from New England southward to the West Indies and in the Gulf of Mexico.

Eupomatus protulicola (Benedict), 1887

Hydroides protulicola Benedict, 1887, p. 550, figs. 17–23.

Eupomatus protulicola Rioja, 1946, pp. 199–200, figs. 10–13.

This is recorded from Tecolutla, Mexico on shells of *Pinna* by Rioja (1946). The body measures 12 to 20 mm. long and 1 to 1.5 mm. wide. The basal disk of the operculum is infundibular, with 34 to 40 denticulations at the margin. The distal processes are arranged in a circlet of 12 to 13, about equally large, distally recurved, outwardly directed spines.

This is otherwise known from Cape Hatteras, North Carolina.

Eupomatus sanctae-crucis (Mörch), 1863

Hydroides (Eupomatus) dianthoides Augener, 1922, p. 49.

Hydroides sanctae-crucis Fauvel, 1919, pp. 478–479, fig. 23.

This is described from eastern Mexico by Augener (1922). The species is distinguishable from *E. dianthus* (above) in its opercular processes, especially those of the distal series. The shorter ones have a short boss or spine, about half way down, on the side facing the center and the outer side is geniculate near the same place, on its outer side.

Eupomatus floridanus Bush (1910) from southern Florida, is probably the same. Its known distribution includes the West Indies. It is not yet known from the environs of the Mississippi delta.

Pomatoceros minutus Rioja, 1941

Pomatoceros minutus Rioja, 1941, pp. 734–738, pl. 9, figs. 15–26; Rioja, 1946, pp. 201–202.

This occurs at Veracruz, Mexico (Rioja, 1946). The tubes are small, 5–6 mm. long, and conspicuously ridged and transversely pitted. They form colonies in branching hydroids. The body is 3 to 4 mm. long or less. This is known also from western Mexico.

Pomatoceros (Pomatoleios) caerulescens Augener, 1922

Pomatoceros (Pomatoleios) caerulescens Augener, 1922, p. 50.

This was originally described from Campeche Bank, lower end of the Gulf of Mexico. The species and subgenus is characterized for lacking buccal setae. The operculum is on the left side, is distally flat and lacks processes. On the tentacular crown there are about 17 pairs of radioles. Total length of the body, including operculum, is about 13 mm. It remains known only from its original locality.

Protula tubularia (Montagu), 1803

Protula tubularia Fauvel, 1927, p. 382, fig. 130; Monro, 1933, pp. 267–268.

Several specimens were dredged off the Florida Keys in 117 fms., by the M/V OREGON, station 243. The species is recorded from Dry Tortugas, Florida by Monro (1933). The cylindrical white tubes are nearly smooth and straight; they measure to 80 mm. long, based on the present finds.

The species is widely known from circummundane areas.

Salmacina dysteri (Huxley), 1855

Salmacina dysteri Fauvel, 1927, pp. 377–378, fig. 129; Rioja, 1946, p. 202.

Colonial tube clusters come from the tubes of a large sabellid, *Sabellastarte* (see above) at Veracruz, Mexico (Rioja, 1946). The tubes form compact masses, are known to occur on under sides of stones, under piers and in crevices. The species is known from cosmopolitan areas.

Mercierellopsis prietoi Rioja, 1945

Mercierellopsis prietoi Rioja, 1945, pp. 411–417, 2 pls.

This is described from between Tabasco and Veracruz, Mexico in brackish water, on submerged trunks of trees, associated with barnacles, oysters and nereids. The tubes form masses. The body is 8 to 10 mm. long and about 0.5 mm. wide. The operculum is distally expanded, somewhat as in species of *Vermiliopsis* (see below); the distal end is expanded as a plaque that lacks spinous processes.

This is known only from the type locality.

Vermiliopsis annulata (Schmarda), 1861

Vermilia annulata Ehlers, 1887, pp. 308–313, pl. 58, figs. 12–16.

Vermiliopsis annulata Rioja, 1946, p. 201.

This is recorded off Florida in 292–310 fms. by Ehlers (1887) and at Tecolutla, Mexico, on mollusk shells by Rioja (1946). It is typically a West Indian species.

Vermiliopsis bermudensis (Bush), 1907

Vermiliopsis bermudensis Hartman, 1942, pp. 90, figs. 154, 155.

Vermilia bermudensis Rioja, 1946, pp. 200–201.

This occurs at Tecolutla, Mexico, on mollusk shells (Rioja, 1946). The white tubes are characterized for having 5 longitudinal ridges of which 2 are stronger than the others and alternate with them. The operculum is vesicular and distally pointed. The species is more widely known from Bermuda.

Dexiospira spirillum (Linnaeus), 1758

Spirorbis (Dexiospira) spirillum Fauvel, 1927, pp. 392–393, fig. 132.

Many tubes attached to strands of turtle or ribbon grass, come from southern Texas. The neatly spiraled, dextrally apertured tubes have a heavier white median line which is bounded on each side by translucent, closely fenestrated bands; otherwise the tube is chalky white. An unbroken aperture is nearly circular. The tubes are entirely attached on one side. The spiral consists of 2 complete turns at maximum development. On the body there are 3 thoracic setigerous segments. Total length is about 1.66 mm. or less.

This is regarded as a cosmopolitan species.

Dexiospira corrugatus (Montagu), 1803

Spirorbis (Dexiospira) corrugatus Fauvel, 1927, pp. 393–394, fig. 133.

Many tubes come from Biloxi, Mississippi, in summer of 1942, on blades of turtle grass (coll. A. E. Hartman). Tubes are white, have a dextral aperture and 3 longitudinal ridges on the upper surface. On the body there are 3 thoracic setigerous segments.

The species is widely distributed geographically and occurs especially on algae such as *Sargassum*.

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Brackish-Water and Marine Assemblages of the Texas Coast, With Special Reference to Mollusks

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U. S. Geological Survey

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Brackish-Water and Marine Assemblages of the Texas Coast, With Special Reference to Mollusks[1]

ABSTRACT

Dredging in the coastal waters in the area lying northeast of Corpus Christi revealed a number of distinct faunal facies, the distribution of which appears to be controlled primarily by salinity and secondarily by type of bottom and other ecologic factors. Shelled mollusks are an important constituent in all facies and are given special attention. Characteristic assemblages found in the following areas are recognized and briefly described: closed bays, polyhaline bays, a highly saline lagoon, passes, beaches on the open Gulf, and shallow waters of the open Gulf. In the closed bays three subfacies are recognized—one in the bay heads, one on the reefs, and one in the inter-reef areas; in the open Gulf the assemblages living close to shore are differentiated from those found 2 to 4 miles off shore. In most stations each facies is characterized by an abundance of certain living forms. Dead shells and other skeletal parts are much more widely distributed but many such strays may be recognized as transported elements by their rarity or by their eroded surfaces. Each group of organisms has one or more centers of maximum development in numbers of species. The Foraminifera, for example, attain their greatest development in the polyhaline bays and near the heads of passes, the ostracodes near the bay heads, mollusks in the polyhaline bays and in the Gulf, and diatoms under normal marine conditions in the Gulf. The reef assemblage of the closed bays is poor in numbers of species, but the individuals are so numerous that they form extensive deposits.

Distinctive features of each assemblage of dead shells are pointed out and it is believed that these features will be useful in recognizing similar facies encountered in drilling.

INTRODUCTION

Location

As shown in Figure 1, the area investigated lies chiefly in San Patricio, Aransas, and Calhoun Counties. Some observations also were made in nearby counties.

Purpose, Scope, and Methods

In 1940 the writer undertook the study of a large collection of cuttings from a series of shallow wells drilled along the Texas coast in the area immediately northeast of Corpus Christi. A preliminary examination of the samples from the wells, which were collected at one-foot intervals, revealed the presence of richly fossiliferous beds. Some of these beds appeared to continue for appreciable distances along the coast and for shorter distances inland. Many of the fossil beds contained

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[1]Publication authorized by the Director, U. S. Geological Survey.

assemblages of mollusks that seemed to record distinct facies of deposition. Collections of Recent mollusks at the U. S. National Museum were examined and the literature searched to obtain data needed in the interpretation of the fossil assemblages. Neither source revealed adequate data, and it was therefore decided to dredge the coastal bays and the near-shore waters of the Gulf of Mexico to obtain information on facies distribution.

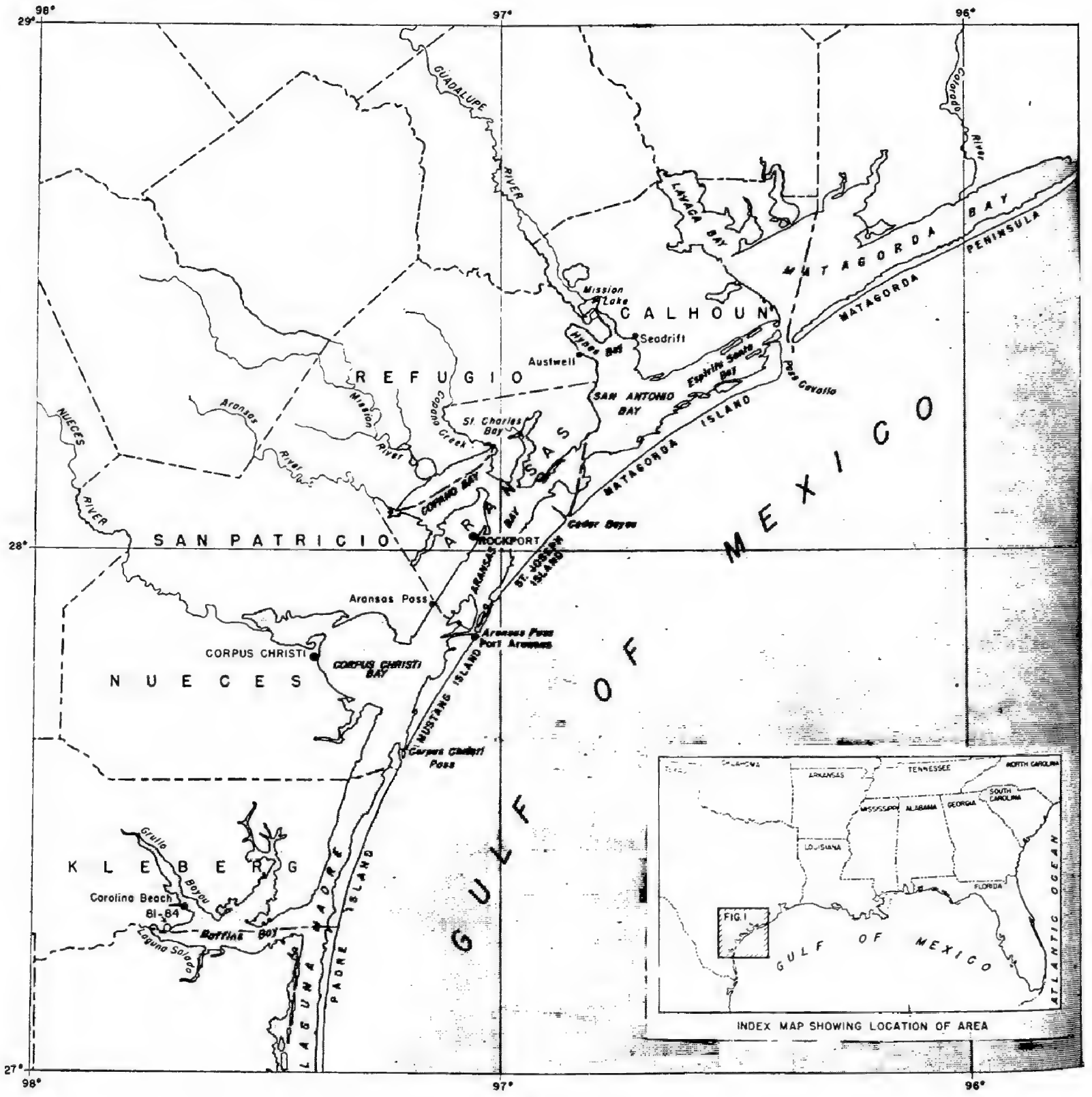

FIGURE 1

Index map showing locations of area and stations in Laguna Madre area.

Dredging and other collecting was done during a period of two months in the summer of 1940. About 60 hauls were made with a bag dredge (rectangular opening 12 by 24 inches, 3-foot bag) towed behind a motor launch. Dredge sites were spaced from the bay heads near river mouths through the bays and passes into the

open Gulf. Dredging returns were satisfactory on the whole, but no deep borers such as *Tagelus* were collected alive. Collections in the shallow waters close to shore were made with a small wire basket dredge—the Lewis dredge (opening 5 by 10 inches)—attached to a stick. The Lewis dredge and a small bag dredge (opening 5 by 12 inches) that could be cast into the surf were used on the beaches in searching for living forms in shallow water. Dredging stations were located by compass bearings. This method is not accurate, but it was believed to be sufficiently exact for the purpose of the investigation. All stations in the main area studied are shown on Figure 2; stations on Laguna Madre are shown on Figure 1.

The ecology was not comprehensively investigated, as the chief purpose was to acquire data on distribution that would aid in interpreting collections from wells. In studying the collections, the living forms were segregated from the dead shells, and this distinction is recorded in Table 1. The species listed in Table 1 are arranged primarily in order of their appearance alive along the salinity gradient from the bay heads to the Gulf. Occurrences of dead shells are also recorded, as it is this assemblage of dead shells (the thanatocoenoses)[7] that is most apt to give data useful in interpreting the shell beds encountered in drilling.

All of the common mollusks in the collections are included in Table 1 or in the list given on page 138. Some of the forms that are identified with described species show unusual features that may eventually lead to the recognition of new species or subspecies.

Earlier Work

So far as the writer is aware, no general description of the changing faunal relationships of the mollusks through the bays and passes to the open Gulf has previously been presented though Gunter (1945, 1950) covered this field so far as the fishes and larger motile invertebrates are concerned. Some data on the mollusca were presented, but he did not dredge and thus did not cover the fauna of the bottom. Galtsoff (1931) made a survey of the oyster resources, and Reed (1941) published a paper describing certain aspects of the marine life in Texas waters. Whitten, *et al.* (1950) described the jetty fauna. A group of oil geologists headed by F. W. Rolshausen have done some dredging in the near-shore waters of the Gulf, but the results of these investigations have not yet been published. Recently Collier and Hedgpeth (1950) have published the results of a detailed hydrographic study of a part of the area. These and other papers dealing with the ecology of the area are listed under "References and Bibliography."

ACKNOWLEDGMENTS

The writer is indebted to Mr. Samuel F. Turner of the U. S. Geological Survey for information about the area and for the opportunity of studying his collection of Texas shells prior to undertaking the dredging program. Dredges and other equipment were furnished by the Division of Mollusks, U. S. National Museum. The Bureau of the Biological Survey through Mr. James C. Stephenson, then Manager of the Aransas National Wildlife Refuge near Austwell, loaned a launch and the services of a boatman for a total of 5 days' dredging. The Texas Game, Fish and Oyster Commission, through Mr. J. B. Arnold, Director of the Coastal

Division, co-operated fully by furnishing the launch *Jobetsy* and a boatman for dredging in the bays and in the open Gulf. Dr. Gordon Gunter, then marine biologist with the Commission, was of great assistance; in addition to being the writer's companion on many collecting trips, he determined the salinity of the water samples collected. Mr. Clyde T. Reed, author of a report on the marine life of the area, conducted the writer to several collecting localities. To Dr. W. Armstrong Price, consulting geologist at Corpus Christi, the writer is indebted for numerous courtesies.

My thanks are due a number of individuals for identifying invertebrates in several groups, as follows: Dr. R. S. Bassler, bryozoans; Dr. Austin H. Clark, echinoderms; Mr. K. E. Lohman, diatoms; Dr. Marian Pettibone, serpulids; Mrs. Rita Post, foraminifers; Dr. John W. Wells, corals. A special report on the Foraminifera by Mrs. Post accompanies the present paper.

PHYSICAL ENVIRONMENT

General Relations

Along most of the coast of Texas and along all of the area under consideration there is a well-developed line of barrier islands separating the low coastal lands and their bays from the waters of the open Gulf. On the south the barrier (Padre Island) is narrow and unbroken for a distance of 130 miles, enclosing a highly saline lagoon known as Laguna Madre. Northeastward the barrier continues as a series of elongate islands separated at their ends by passes and shutting off a series of irregular, shallow, brackish-water bays. In many places these bays may be divided into two series: (1) large irregular "front bays" that are connected with the Gulf through passes and (2) smaller "back bays" into which coastal streams drain. Geographically this is a convenient basis on which to subdivide the area but one that could not be used without modification in the present study. When the bays faunas were examined it was found that changes in the assemblages were more closely tied to changes in salinity than to geographic position relative to the Gulf shore. Thus, front bays that are directly connected with the Gulf and have a comparatively high salinity support a distinctive assemblage, at least in their lower more saline parts; but other front bays not directly connected with the Gulf have assemblages that resemble those of the back bays. In this paper, therefore, the terms *polyhaline bay* and *closed bay* are substituted for *front bay* and *back bay*.[2] In Aransas Bay the closed-bay fauna was found in the upper part of the bay, the polyhaline-bay fauna in the lower part of the bay and a boundary was drawn to differentiate the two (Fig. 2). The boundaries between the several facies are admittedly not as clearly marked in the field as they are on the map (Fig. 2), but the faunal changes that take place from the bay heads to the Gulf are just as real as the changes in the salinity gradient and, like the changes in salinity, they tend to be gradual. In surveying the faunas from the bay heads to the Gulf, it becomes apparent that certain abundant and characteristic forms die out or become reduced in size and numbers while others do just the reverse; in addition, new forms appear.

[2]The term *polyhaline* is widely applied by Europeans to brackish waters that range in salinity from 16.5 to 40 o/oo (Dahl, 1948, pp. 11–13). The term thus seems an appropriate one to use in referring to the more saline parts of the coastal bays in Texas and the assemblage of organisms living in these waters.

There are, however, certain changes that appear to be fairly abrupt. For example, living examples of the brackish-water forms such as *Rangia cuneata* and *Littoridina sphinctostoma* disappear rather suddenly as the waters become more salty; similarly, rather definite boundaries limit the areas of oyster reefs. The reef-building oysters have a number of essential requirements, and one of the most important for their optimum environment is salinity about midway between that of fresh water and that of normal sea water. If this condition is met, and other features are favorable, reefs will be developed. In Aransas Bay, for example, the required salinity probably is responsible for the restriction of the best-developed reefs to the upper part of the bay (Collier and Hedgpeth, 1950, p. 154). Oysters that are smaller in size and numbers are found living all the way from the closed bays to Aransas Pass but they do not make reefs in the saltier waters.

Since the coastal lands in this general area are very low the streams are sluggish and even in times of flood bring only sand and finer sediment to the bays. Coarser material in the form of shells, however, is abundant in all of the coastal waters from the bays to the beaches of the open Gulf. Over a period of time the amount of silt brought to the bays by the rivers is tremendous; yet, as Collier and Hedgpeth pointed out (1950, p. 130), the depths of the bays appear to remain fairly constant except in a few restricted areas where delta building is in progress. In this connection Price (1947) has shown that there is an equilibrium between the forms of the bays and the natural forces operating on them. Along certain of the passes and in parts of the polyhaline bays there are artificial jetties and similar structures made of large blocks of granite brought in for engineering purposes. These structures form favorable niches for rock-clinging mollusks and other forms that have limited opportunities to settle in other parts of the area.

The bays are very shallow; in the area here considered, depths exceeding 9 feet are found only in parts of Aransas Bay. The bay heads in most places have mud bottoms and so do the deeper parts of bays nearer the Gulf. The waters near the bay shores are very shallow, covering flats made up of mud or sand or coarse shell. In the closed-bay areas that lie between the bay heads and the polyhaline bays oyster reefs may be developed, but these reefs cover only a small part of the area; by far the greater part of the area is soft mud.

As noted in the brief descriptions of individual dredge hauls, many of the muds contain plates of selenite; and this material apparently is being deposited widely in the bays and at some places even in the waters of the Gulf itself. Earlier workers have noted similar occurrences. Baker (1929, p. 28) stated that selenite was dredged from the channel cut between Brazos Santiago and Point Isabel at the south end of Laguna Madre and from the strait connecting the Gulf and the lagoon. The annual rainfall in this area is about 25 inches. In the same paper he stated that gypsum is deposited in areas where the annual rainfall is between 20 and 36 inches. These limits would include all of the area considered in the present report. Price and Gunter (1942) in discussing the Laguna Madre area, note that dredge-boats occasionally find large masses of crystalline and alabaster gypsum in the coastal bays.

The waters of the Gulf off the barrier islands are shallow and the mean tidal range is about a foot, the extreme range being only 1½ to 2 feet. Even on such a low coast this is not an important amount, and favorable tides do not regularly uncover wide flats for inspection. Indeed, the strength and direction of wind may

be far more important factors than the tide. An onshore wind may bring the Gulf waters above high tide level at a time when the tide would otherwise be low. Offshore northerly winds such as those that blow during the winter may depress the water surface 2 or 3 feet below mean low Gulf level. Periodically the coast suffers from severe hurricanes and the resulting high waters may change the configuration of the passes that connect the bays to the Gulf as well as alter temporarily the salinities of the coastal bays.

Salinity

In the area under consideration the salinity gradient is fairly stable from the river-mouth areas, where the waters are practically fresh, through the bays and passes to the Gulf with its normal sea water. A survey made by Galtsoff in 1926 (Galtsoff, 1931) covered most of the area later studied by the writer. A more detailed hydrographic study by Collier and Hedgpeth dealt primarily with Copano Bay, Aransas Bay, and Laguna Madre. Basic field data for their study were obtained by Collier in 1936–38, supplemented by additional data gathered by Gunter and Hedgpeth at later dates (Collier and Hedgpeth, 1950). Observations on the salinities of various parts of the area were also published by Gunter (1941b, 1945, 1950). The writer found the results of these several surveys invaluable, as only a few salinity determinations and temperature readings were made during the present study.

Data obtained from the above-mentioned sources indicate clearly that the changes in the faunal assemblages from the river mouths to the Gulf are closely correlated with changes in the salinity gradient. Unfortunately no salinity determinations have been made of Mission Lake or the upper part of St. Charles Bay, but in the other areas where the bay-head facies is recognized—namely in Hynes Bay and the upper part of San Antonio Bay—the salinity increases gradually from 4 o/oo near the middle of Hynes Bay to 9 o/oo in the vicinity of Webb Point (Fig. 2) in San Antonio Bay. In the remaining parts of the closed bays the salinity in general increases as the polyhaline bays and passes are approached. In the lower part of San Antonio Bay saline water from Pass Cavallo works its way southwestward through Espiritu Santo Bay and pushes the isohalines westward in San Antonio Bay. As a result, salinities in the lower part of this bay decrease from 17 o/oo on the east to 10 o/oo on the southwest at its junction with Mesquite Bay. In Mesquite Bay, which has an intermittent and shallow connection with the Gulf through Cedar Bayou, the salinity may be as high as 23 o/oo near the bay entrance to the Bayou, decreasing rapidly toward San Antonio Bay on the one side and toward Aransas Bay on the other. In Aransas Bay salinities increase progressively from about 13 o/oo at its northeast end to 20 or 25 o/oo near the entrance to Lydia Ann Channel and Aransas Pass. Off Rockport, where in the present report a boundary is drawn between the closed-bay and open-bay facies, the salinity is 15 o/oo to 20 o/oo. These remarks apply to normal years. The recent long drought (1950–51) on the south Texas coast, has caused the bay salinities to rise much higher (Gunter, written communication).

Copano Bay, a closed bay lying to the northwest of Aransas Bay, has salinities that range from 7 o/oo on the west to 19 o/oo near its junction with Aransas Bay. This range is comparable with that of other closed-bay areas.

In Lydia Ann Channel the salinity increases steadily to 27 o/oo near its junction with the main section of Aransas Pass. The gradient continues to increase through the Pass, reaching 32 o/oo in the Gulf itself.

The figures mentioned above refer to surface salinities and are average figures. The readings at any given spot vary with the tide and the wind. There is also, of course, a seasonal variation, with highest salinities recorded at the end of summer. Gunter states (1945, p. 19) that in August and September in 1941 the salinity of Aransas Bay in spots exceeded that of the Gulf. One of his high readings was on the flats of The Cove south of Rockport, the other on the bottom in Lydia Ann Channel. The salinity of the water on the bottom is in general higher than that at the surface, and this may be particularly important in the shallow upper reaches of the bays where the surface waters are nearly or quite fresh—yet the waters immediately over the bottom muds are sufficiently saline to support an abundant fauna of foraminifers. Gunter found that in Copano Bay the average salinity at the bottom was 9.7 o/oo whereas that at the surface was 9.2 o/oo. In Aransas Bay the average figures were 21.7 o/oo at the bottom, 20 o/oo at the surface; in the Gulf the average bottom salinity was 36.1 o/oo, that at the surface 32.8 o/oo. In the bays in the bottom of burrows the salinity may be even higher than that of the waters immediately over the floor of the bay.

Under ordinary conditions the salinity gradient is fairly stable, but at intervals it and other environmental conditions may be radically upset by storms of several sorts. Floods of fresh water from the land on occasion flow out over the salt and brackish water of the bays and passes. Hurricanes from the Gulf likewise strike the area and raise the salinities of the coastal bays. Severe storms may also come from the land, and at intervals the "northers" that arrive in winter may bring severe cold that adversely affects the life in the bays and in the Gulf itself. Gunter (1941a) has given an impressive picture of the devastating effects of a storm that visited the area in January of 1940 (the year of the dredging here described). In shallow arms of the bays where high waves were absent the water froze for distances of a mile. In other bays mush ice formed and was washed up on the shore. The fish life was most severely affected—Gunter estimated that at least a million pounds succumbed—but some shallow oyster reefs were killed by the cold and by the exposure above water during the low tide brought on by the "norther." In the Gulf thousands of mollusks and starfishes were rolled ashore on the beaches. These invertebrates live just off the beaches and unless numbed by cold are not rolled in by heavy surf.

All of the above-mentioned environmental changes, however, are temporary and affect the area only at intervals. As Gunter has pointed out (1941b, pp. 11–12) the area is in many ways an ideal one for ecologic studies, particularly for studies involving the relations of organisms to the salinity of their environment.

FACIES

Closed Bays

Closed bays tend to be more irregular in size and shape than polyhaline bays and many are elongated at right angles to the coast rather than parallel to it. The streams that enter many of the closed bays freshen the bay waters. An exception to this rule is Baffin's Bay; it receives drainage from the land at intervals but

because of its location in an area of little rainfall, high evaporation, and porous soil which absorbs much of the surface runoff, it becomes highly saline periodically, as does the much larger Laguna Madre, with which it is connected.

Three facies, or subfacies, may be recognized in the closed bay areas, each characterized by fairly distinctive sediments and fauna. One is developed in the upper reaches of the bays near the mouths of streams, where the waters are 2 to 5 feet deep and the bottom usually very soft mud. Salinities in these areas range from fresh (at least at the surface) to about 9 o/oo. The bottom fauna is meager; it is characterized by an abundance of heavy-shelled Rangias and delicate ostracodes with many foraminifers of three genera *Rotalia, Elphidium,* and *Nonion.* Arenaceous forms may also be present in small numbers;[3] locally the brackish-water snail *Littoridina sphinctostoma* and the thin-shelled *Tellina texana* may be very abundant. Living examples of *Mulinia lateralis,* the razor clam *Ensis minor,* and barnacles also occur in this facies, but they are equally or more numerous in other parts of the area.

Rangia is generally recognized as an estuarine genus; in the present study living examples were found almost exclusively in the bay-head facies (Table 1). In the nearly fresh waters of Mission Lake, which lies on the landward side of the mouths of the Guadalupe River, the specimens of *Rangia cuneata* were more than twice the size of numerous specimens taken in somewhat more saline waters. In the extensive collections of the U. S. National Museum there is only one lot of Rangias in which the shells are comparable in size to those obtained in Mission Lake. This lot (USNM 126761) was collected from a "Lake near mouth of Carancahua Bay, Texas," in waters noted to be "slightly brackish." This evidence suggests that *Rangia* is one of the few fresh-water forms that has invaded brackish water and that they flourish and live longer in waters that are practically fresh. *Rangia,* on the other hand, may belong to the marine group mentioned by Shimer (1908, p. 474) as having become so thoroughly adapted to brackish water that they attain their largest size there. Andrews (1940) mentions other examples of this sort. Additional collecting in the uppermost reaches of the bays may give more convincing evidence about *Rangia* and its position.

In the parts of the closed-bay areas lying below the bay heads (Fig. 2) two facies or subfacies are recognized—the reef and the inter-reef. The inter-reef areas should be discussed first because they are more like the bay-head areas than are the reefs. The bays between reefs average 5 feet in depth, with a maximum of 10 feet. For the most part the bottom is covered by gray or bluish muds but in a few places near shore by fairly clean sand. The inter-reef areas are not dominated by any particular forms. The same three genera of foraminifers that occur in the bay-head facies are found in abundance almost everywhere mixed with a fair variety of mollusks, most of which are represented by dead shells. *Rangia* and *Littoridina* are absent in most places.

The assemblage in the reef areas is unique. The dominant forms are the oysters *(Crassostrea virginica)* and the mussels *(Mytilus recurvus),* together with a variety of smaller forms that are cemented to or cling to these larger shells—bryozoans,

[3]The Foraminifera were not studied in the field and no specimens were preserved for tests for protoplasm at a later date but the pattern of distribution clearly suggests that most of those obtained by dredging and bottom sampling were alive when collected.

Crepidulas, barnacles, and serpulid worms. On some reefs there is an abundance of small gastropods such as *Odostomia* and *Anachis;* and the thick dorsal parts of the large oysters are bored by the small clam *Martesia.* Reefs are developed from the surface to depths of 9 feet. Examples were examined and sampled in St. Charles, Copano, and Aransas Bays but not in San Antonio and Mesquite Bays, though they are known to occur in both areas.

The ubiquitous mussels[4] are larger and more numerous in the upper reaches of the bays. In these areas they are a real menace to the oysters for they compete with the oysters for food and literally cover them.

Table 1[5] also records the occurrence in the closed bays of a number of shells of species that were found living only in more saline waters. Most such occurrences are rarities (1 or 2 specimens only) and most of the shells are worn or broken. Some of these "strays" may have crossed the border during periods of shifting salinities; others may have been carried in the stomachs of water birds or fish, and still others, especially gastropods, may have been trundled in by hermit crabs. Small shells of *Donax,* a clam that in Texas lives exclusively on the Gulf beaches at the water's edge, were found at Station 6 in the bay-head facies and in an oyster reef at the head of Aransas Bay. These may well have been carried in by gulls; and a bird or a fish may have brought in the small piece of worn coral taken at Station 35 at the upper end of Aransas Bay. Conceivably storms could wash in some strays, but dredging in fresh-water ponds near the bays brought up no fragments of marine shells.

Polyhaline Bays

The more saline waters of the polyhaline bays contain a far richer and more varied fauna than is to be found anywhere in the closed bays. (Gunter, 1947, noted that such an increase in numbers of organisms usually is found in passing from brackish to marine waters.) An examination of Table 1 shows that some 30 species, none of which lives in the closed bays, were collected alive in the polyhaline bays for the first time. These need not be enumerated here, but it may be pointed out that the list includes forms that ordinarily are regarded as typically marine. At Station 45, located 1 mile south of Rockport and near the border of the closed bay boundary, sand dollars live near shore in considerable numbers; another mile to the south, at Station 46, a small ophiuroid was collected and the coral *Astrangia* was found in fair-sized clumps attached to shells of several sorts. The average bottom salinity in this area is between 16 and 19 o/oo and the coral occurrence is therefore not unusual; Ferguson (1948) has shown lethal dilutions for *Astrangia* to be 10 parts per 1,000 of sodium chloride.

Other Areas

In Aransas Pass, where the waters are deeper and more saline, a number of forms were taken alive for the first time; and in the waters of the open Gulf still others

[4]Fox, Marks, and Austin (1936) determined that one species of *Mytilus* can survive in water of half normal salinity and in water containing one-third again as much salt as normal sea water (range 17 o/oo to 45 o/oo).

[5]In Table 1 there are half a dozen stations from which no Foraminifera are recorded. These stations include oyster reefs—where collecting was done with tongs—wharf piling, etc., from which no fines were collected.

were taken. From a glance at Table 1, however, it is apparent that the bottom fauna of the nearshore shallow waters of the open Gulf is comparatively meager and that the richest assemblages frequent the polyhaline bays and the passes.

Bottom samples were collected at 58 stations from the bay heads to the Gulf, and all were examined for diatoms by K. E. Lohman. Diatoms were found in 12 samples, but in no sample was there a rich assemblage; the greatest variety of forms was found in the open Gulf. The rarity of diatoms in all the samples and their complete absence in many was puzzling to Mr. Lohman, who suggested that the deposition of large numbers of diatoms was perhaps prevented by turbulence in the shallow waters due to currents set up by the tide and wind. Diatoms in quantity in plankton from the bays were reported by Galtsoff (1931, p. 13). The paucity of diatoms on the bottom may be explained in terms of sedimentation. Except in a few localities where delta-building in progress, deposition does not seem to be rapid in the bays and their floors are fairly stable. Much of the clay and silt brought to the bays by streams is carried on to the Gulf and with it apparently most of the diatoms. The larger and heavier shells of the benthonic organisms, however, remain in the bays where they lived.

In Table 2 all the organisms identified from the bay heads to the open Gulf (beaches not included) are listed systematically.

TABLE 2

List of Organisms Identified from Bay Heads to Open Gulf
Beaches Not Included

Marine Diatoms
Actinoptychus senarius Ehrenberg
Amphora cf. *A. obtusa* Gregory
Biddulphia longicruris Greville
Biddulphia sp.
Cocconeis sp.
Coscinodiscus cf. *C. devius* Schmidt
Coscinodiscus excentricus Ehrenberg
Coscinodiscus lineatus Ehrenberg
Diploneis cf. *D. bonbus* Ehrenberg
Melosira cf. *M. recedens* Schmidt
Melosira sulcata (Ehrenberg) Kützing
Navicula pennata Schmidt
Nitzchia cf. *N. constricta* (Gregory) Grunow
Pleurosigma sp.
Rhaphoneis amphiceros Ehrenberg
Rhaphoneis surirella (Ehrenberg) Grunow
Rhopalodia gibberula var. *baltica* O. Muller

Phylum Protozoa

Class Sarcodina

Order Foraminifera

Family Lituolidae
Ammobaculites sp.

Family Silicinidae
Miliammina sp.

Family Miliolidae
Quinqueloculina sp.
Miliolinella sp.
Massilina sp.
Spiroloculina sp.
Triloculina sp.

Family Trochamminidae
Trochammina sp.

Family Polymorphinidae
Guttulina sp.

Family Nonionidae
Nonion sp.
Elphidium sp.

Family Buliminidae
Buliminella sp.
Bolivina sp.

Family Rotaliidae
Discorbis sp.
Rotalia sp.

TABLE 2—continued

List of Organisms Identified from Bay Heads to Open Gulf Beaches Not Included

Family Anomalinidae
Cibicides sp.

Phylum Coelenterata

Class Anthozoa

Order Scleractinia

Family Astrangidae
Astrangia astreiformis Milne Edwards and Haime

Phylum Annelida

Class Polychaeta

Family Serpulidae
Chitinopoma sp.

Phylum Bryozoa

Class Gymnolaemata

Order Chilostomata

Family Membraniporidae
Membranipora flabellata Canu

Phylum Echinodermata

Class Asteroidea

Order Phanerozonia
Astropecten marginatus Gray
Astropecten articulatus valencienni Muller and Troschel

Class Ophiuroidea

Ophiuroids

Class Echinoidea
Mellita quinquesperforata (Leske)

Phylum Mollusca

Class Amphineura

Order Polyplacophora

Family Ischnochitonidae
Ischnochiton papillosa (Adams)

Class Pelecypoda

Order Prionodesmacea

Family Nuculanidae
Nuculana acuta Conrad
Nuculana concentrica Say

Family Arcidae
Arca campechiensis Gmelin
Arca incongrua Say
Arca transversa Say

Family Noetidae
Eontia ponderosa (Say)

Family Pinnidae
Atrina species

Family Ostreidae
Crassostrea virginica (Gmelin)

Family Pectinidae
Pecten irradians amplicostatus Dall

Family Anomiidae
Anomia simplex Orbigny

Family Mytilidae
Mytilus recurvus Rafinesque
Modiolus tulipus Linnaeus

Family Periplomatidae
Periploma inequivalvis C. B. Adams

Family Pandoridae
Pandora trilineata Say

Family Lyonsiidae
Lyonsia floridana Conrad

Order Teleodesmacea

Family Cyrenidae
Polymesoda floridana Conrad

Family Crassatellidae
Crassinella species

Family Carditidae
Cardita floridana Conrad

Family Lucinidae
Lucina pectinata Gmelin
Lucina floridana Conrad
Lucina multilineata Tuomey and Holmes
Lucina amianta Dall

Family Cardiidae
Cardium muricatum Linnaeus
Cardium robustum Solander
Laevicardium mortoni Conrad

Family Veneridae
Dosinia discus Reeve

TABLE 2—continued

List of Organisms Identified from Bay Heads to Open Gulf Beaches Not Included

Cyclinella tenuis Récluz
Chione cancellata Linnaeus
Chione grus Holmes
Venus mercenaria Linnaeus
Venus campechiensis texana Dall
Anomalocardia cuneimeris Conrad

Family Petricolidae
Petricola pholadiformis Lamarck

Family Tellinidae
Tellina alternata Say
Tellina versicolor Cozzens
Tellina texana Dall
Macoma constricta Bruguière
Strigilla flexuosa Say
Tellidora cristata Récluz

Family Semelidae
Semele sp.
Abra aequalis Say
Cumingia tellinoides vanhyningi Rehder

Family Donacidae
Donax sp.

Family Sanguinolariidae
Tagelus gibbus Spengler
Ensis minor Dall

Family Mactridae
Mactra fragilis Gmelin
Mulinia lateralis Say
Rangia cuneata Gray

Family Corbulidae
Corbula sp.
Paramya subovata Conrad

Family Pholadidae
Barnea costata Linnaeus
Martesia sp.

Class Scaphopoda

Family Dentaliidae
Dentalium texasianum Philippi

Class Gastropoda

Order Archaeogastropoda

Family Fissurellidae
Fissurella sp.
Diodora sp.

Family Cyclostrematidae
Cyclostremicus species
Teinostoma sp.
Vitrinella cf. *V. helicoidea* C. B. Adams
Vitrinella sp.
Vitrinella? sp.

Family Neritidae
Neritina virginea Linnaeus

Order Mesogastropoda

Family Epitoniidae
Epitonium sp.

Family Melanellidae
Melanella sp.

Family Pyramidellidae
Pyramidella sp.
Turbonilla sp.
Odostomia sp.

Family Naticidae
Natica pusilla Say
Polinices duplicata Say

Family Crepidulidae
Crepidula convexa Say
Crepidula plana Say

Family Amnicolidae
Littoridina sphinctostoma Abbott and Ladd

Family Rissoidae
Rissoina sp.

Family Littorinidae
Littorina ziczac Gmelin

Family Vermetidae
Vermicularia spirata Philippi

Family Caecidae
Caecum sp.
Meioceras sp.

Family Modulidae
Modulus modulus Conrad

Family Triphoridae
Triphora sp.

Family Cerithiidae
Cerithium variable C. B. Adams
Cerithidea pliculosa (Menke)

TABLE 2—continued

List of Organisms Identified from Bay Heads to Open Gulf Beaches Not Included

Bittium varium Pfeiffer

Family Thaisidae
Thais floridana Conrad

Family Pyrenidae
Anachis avara Say
Anachis obesa C. B. Adams
Mitrella lunata Say

Family Nassariidae
Nassarius vibex Say
Nassarius acutus Say

Family Buccinidae
Cantharus cancellaria Conrad

Family Neptuneidae
Busycon contrarium (Conrad)
Busycon pyrum Dillwyn

Family Olividae
Oliva sayana Ravenel
Olivella mutica Say

Family Turridae
Kurtziella sp.

Subclass Opisthobranchia

Order Pleurocoela

Family Actaeonidae
Actaeon punctostriatus C. B. Adams

Family Acteocinidae
Acteocina canaliculata Say

Family Bullidae
Bulla striata Bruguière

Family Siphonariidae
Siphonaria naufraga Stearns

Bay-head Facies

Dredge hauls were made far inland near the heads of closed bays and close to the mouths of streams. The first of these was in a small body of water known as Mission Lake, a landward extension of one of the arms of San Antonio Bay into which empty the two mouths of the Guadalupe River (Fig. 2). Several hauls were made in Hynes Bay and the upper part of San Antonio Bay to the southwest. Three hauls were made near the head of tortuous St. Charles Bay, where four creeks enter through swampy channels (Fig. 2).

Mission Lake

Mission Lake is a very shallow body of water about 3 miles long and half a mile wide. The dredging was done near its junction with Guadalupe Bay, about 800 feet off shore in mud under 2 feet of water (Fig. 2, Sta. 1). The bottom was so soft that in wading one sank a foot or more. Fine weed grows in the mud, which is dark gray, contains dead land shells and water-logged pieces of wood, and smells of vegetable decay. The dredge brought up three unusually large living specimens of *Rangia cuneata* but no other large forms.

A sample of the soupy mud when allowed to settle and dry became a dark gray to nearly black waxy clay with streaks of lighter sandy material; borders between the sand and clay are sharp and probably represent bedding disturbed in dredging; white fragile shells of ostracodes, including paired valves, which apparently were alive at the time of dredging, are scattered through both light and dark material.

The residue after the removal of the clay by washing is a fine sand composed of angular to subangular grains of clear to milky quartz measuring 0.05 to 0.20 mm

in maximum diameter together with the shells of ostracodes and foraminifers. Floatings prepared from the washed residue consist chiefly of Foraminifera belonging to three genera: *Rotalia, Elphidium,* and *Nonion.*

Hynes Bay

Hynes Bay is larger than Mission Lake. It measures 5 by 2½ miles and has a maximum depth of 4 feet, but parts of it are so shallow that in crossing the bay small launches scrape periodically on projecting shells.

A dredge run was made near the head of the bay in mud under 2 to 2½ feet of water (Sta. 2). Washing and sieving of the dredged mud brought out several moderate-sized living specimens of *Rangia cuneata* and many living examples of the thin-shelled *Tellina texana;* a residue of shell waste consisted chiefly of small valves of *Mulinia lateralis* and *Rangia cuneata,* with numerous specimens of *Littoridina,* a *Succinea,* and fragments of barnacles.

A sample of the bottom mud dried to a very dark, slightly waxy clay with scattered bits of shell and some sand grains. When washed this material yielded a fine quartz sand in which most of the grains are clear and sharply angular, averaging 0.25 mm in maximum diameter. Present also in abundance are subcircular or elliptical plates of gypsum (selenite) averaging 0.5 mm in diameter and pierced obliquely in the center by another smaller crystal of selenite.

A rich concentrate of Foraminifera shells was floated from the washings. The assemblage included a rare arenaceous form, three species of *Elphidium* (one in great abundance), *Nonion,* and *Rotalia.* Ostracode valves were rare.

A dredge haul at the lower end of the western lobe of Hynes Bay near its junction with the larger eastern lobe yielded many bivalves (chiefly *Rangia* and *Tellina*) that live on a bottom composed partly of dark-gray mud mixed with shell and partly of sand under 3½ to 4 feet of water (Sta. 3). The water was muddy at the time of dredging; its salinity was not measured but it tasted fresh. According to reports, ducks visit this general area to feed on the thin-shelled Tellinas.

The shelly waste, with bits of wood, washed from the dredged material consisted largely of bivalve shells *(Rangia, Mulinia)* with numerous specimens of *Littoridina.* None of the gastropods appeared to be alive, but the abundance of both adult and young shells indicates that the species lives close by. Several other small gastropods were present but none in abundance. Other forms include barnacles living on the posterior ends of the Rangias and ostracodes (both valves) with fragments of Bryozoa, crabs, etc. When washed, the mud gave a large number of Foraminifera (8 species in the three genera most commonly found in the heads of the bays—*Nonion, Rotalia,* and *Elphidium*) mixed with ostracode valves and fragments of mollusk shells. Present also in washings in great abundance are plates of opaque gypsum similar in size and shape to those found near the head of the bay at Station 2. A small amount of well-sorted sand is also present in the form of grains of sharply angular clear quartz averaging 0.1 mm in diameter.

A haul was made near the head of the large eastern lobe of Hynes Bay close to the passage leading northward toward Mission Lake. This locality (Sta. 4) was about 600 feet offshore in clean hard sand under 2 feet of water. One fairly large *Rangia* was the only living mollusk recovered. The sand is fine but poorly sorted, consisting

largely of grains of glassy quartz that do not exceed 0.25 mm in maximum diameter; most of the grains are angular to subangular but a few are well rounded. A few dark mineral grains are present together with the shells of smaller foraminifers, ostracodes, and worn fragments of mollusks *(Littoridina* and *Ensis)*. The assemblage of Foraminifera is similar to that dredged near the mouths of the rivers: an arenaceous species *(Ammobaculites)*, three species of *Elphidium*, and a *Rotalia*. One genus *(Quinqueloculina)* not observed in Stations 1–3 was represented only by fragmentary shells.

A haul was made in the northeast corner of the bay south of Swan Point. The water at the dredge site (Sta. 5) was 4 feet deep, the bottom composed of sand and sticky mud. No living mollusks were recovered. Washing shows the sand to be poorly sorted and the grains to be as much as 0.35 mm in diameter. Like the sand obtained elsewhere in Hynes Bay, it is composed mainly of angular to subangular grains of clear quartz; soft, chalky, crystals of gypsum are also present. Fragments of mollusks include one small worn valve of *Rangia*. Foraminifera are numerous, and the assemblage is similar to that at other stations in the bay-head facies.

Upper San Antonio Bay

San Antonio Bay is the largest bay in the area studied. It is irregular in outline with a maximum diameter of 15 miles measured parallel to the coast, where it is bounded by Matagorda Island; its width at right angles to the coast is about 10 miles; the average depth of the water is 5 feet, but in a few depressions, mostly in the central part of the bay, the depth is 6 or 7 feet. The Bay lacks a direct connection with the Gulf, and the openings that unite it with bays to the northeast and southwest are constricted by shoals and islands. The waters in the upper (landward) part of the bay, north of Webb Point on the west and Mosquito Point on the east (Fig. 2) are comparatively fresh and carry a fauna similar to that found in Mission Lake and Hynes Bay.

In the northwest corner of San Antonio Bay a haul was made with a hand dredge 500 feet off shore in 1½ feet of water (Sta. 6). The bottom in this area is composed of fairly clean to muddy sand. Though the bottom may be classed as "hard," the upper 2 or 3 inches is comparatively soft. Numerous Rangias plow through this upper layer just below the sandy surface or with the posterior ends of their shells protruding. Many of these pointed posterior ends carry living barnacles. The *Rangia* shells are the only suitable spots for fixation in the area, but they must be exceptionally favorable, owing to the proximity of the siphons. Some of the barnacles, in turn, are encrusted with bryozoans. With the Rangias are a fair number of living Mulinias, a few razor clams, and numerous shells of *Littoridina (Texadina) sphinctostoma;* about one-third of the specimens recovered were alive. Oysters and *Mytilus* and half a dozen species of small mollusks are represented by rare dead shells (Table 1). Among the mollusks was a land shell and a fragment of *Donax*, a genus that lives in great abundance at the water's edge on the Gulf beaches.

The assemblage of Foraminifera in the sand is not impressive. *Rotalia* is the only form present in any abundance but a number of other genera are represented, mostly by rare shells. The sand is similar to that of the closed bays already described, but somewhat cleaner. It is composed mostly of angular to subangular grains of clear quartz and is very fine, only the larger grains reaching a diameter of 0.1 mm.

Examination of nearby areas showed that the Rangias were not equally abundant everywhere. A second dredge haul was made somewhat farther offshore about half a mile to the south (Sta. 7, Fig. 2.) The run started in 2 feet of water over sand and ended in mud under slightly deeper water. The fauna of larger forms was similar to that obtained to the north but the Rangias were notably less abundant. The dredge captured a number of live shrimp. Only a few Foraminifera were present; *Rotalia* again was the most abundant, and it was accompanied by a comparatively few specimens of *Elphidium* and *Nonion.* A few small oysters and other shells were also found (Table 1).

Upper St. Charles Bay

St. Charles Bay in a narrow, irregular body of shallow water extending for 10 miles in a northerly direction with an average width of about a mile. Several creeks empty into it through marshes that fringe most of its shore. The bay itself is one of the feeders to the much larger open Aransas Bay. The maximum depth of water in St. Charles Bay is only 5 feet. Most of the bottom is soft mud but some sand and shell occur. Oyster reefs are developed locally in the lower (southern) half of the bay, and large areas are covered with a growth of widgeon grass.

Three dredge hauls were made near the head of St. Charles Bay, the first in the center of the northernmost lobe close to the mouths of Twin and Burgentine Creeks (Sta. 8). The water in this lobe of the bay is 2 feet deep, and the bottom is a dark gray muddy sand containing a few living Mulinias together with a *Nonion,* numerous *Rotalia,* and scattered valves of ostracodes, many of them broken. The residual sand, when washed free of clay, consists of very poorly sorted angular to subangular grains of glassy quartz ranging in size from 0.05 to 0.5 mm; some grains of gypsum accompany the quartz.

A second haul along the west shore of the upper bay between the mouths of Salt Creek and Cavasso Creek started in 18 inches of water over sand on the northeast and ended in 3 feet of water over mud on the southwest. A few small mollusks were found.

A third haul on the southeast side of the bay and slightly down-bay from the last was in mud under 4 feet of water (Sta. 9). The dried sample is a gray-brown waxy clay with scattered foraminifers and large crystals of selenite. When washed this material yields fine quartz sand, larger pieces of gypsum, many Foraminifera, and a few ostracode valves. The Foraminifera included arenaceous forms, together with representatives of *Elphidium, Nonion,* and three species of *Rotalia.*

Cavasso Creek enters St. Charles Bay about 5 miles below its head. The waters of the creek are distinctly brackish where State Road 35 crosses it 1½ miles above its mouth, but no mollusks were recovered by dredging at this point.

Inter-reef Facies

Lower St. Charles Bay

A run was made in the lower half of St. Charles Bay mostly through widgeon grass growing in muddy sand under 2 feet of water (Sta. 10). The dredge is not very effective under such conditions as far as living mollusks are concerned, but it picked up dozens of small living crabs, some shrimp, and several small fish and a fair

number of dead bivalves, some of them with the valves still hinged together. The commonest species was *Tagelus gibbus,* followed closely by *Lucina pectinata, Macoma constricta,* and *Crassostrea virginica* with its encrusting Bryozoa, barnacles, and serpulid worms. It is probable that all of these forms live in the immediate vicinity.

A sample of the muddy sand was collected at the southeast end of the dredge run. The sand grains are of clear quartz, angular to subangular, and range from 0.05 to 0.30 mm in diameter. Washing and floating yielded very few Foraminifera; the arenaceous *Ammobaculites* is the only common type, but rare specimens of *Rotalia* and *Miliammina* are also included. A dredge run made immediately to the northeast was very similar; no collection saved.

A dredge haul was made in the lower part of St. Charles Bay to the south of Station 10 and 900 to 1,800 feet from the eastern shore (Fig. 2, Sta. 11). The dredging was started on the south in sandy mud under 4 feet of water and was continued northward through increasing amounts of sand to an oyster bed. Very few large mollusks, other than the oysters at the end of the run, were found; there was one live *Ensis,* a few Mulinias, plus miscellaneous small dead shells together with several small live flounders and shrimp.

The sand in the mud at the south end of the run is finer and better sorted than that from the area to the north; along with the small quartz grains are rounded grains of selenite 0.5 in diameter. The assemblage of Foraminifera is likewise somewhat different: by far the most abundant are the Rotalias, but there were large numbers of Elphidiums plus a few specimens of *Nonion;* no arenaceous forms were seen.

A bottom sample was collected from the south end of the bay at the pier at the St. Charles Bay Club, 500 feet from shore, where muddy sand is under 4 feet of water (Sta. 12). The material contained very few shells: a few small, worn, and more or less fragmentary oysters, *Mytilus* (with encrusting bryozoans), *Ensis,* and a single *Bittium* together with plates of barnacles. The washed sand is a fine (average 0.2 mm); most of the grains are angular, some subangular, a few well rounded and frosted. Foraminifera are not abundant. The commonest form is *Rotalia* together with a few specimens of *Nonion, Elphidium, Ammobaculites,* and *Miliammina.*

Copano Bay

Copano Bay is a subrectangular body of water; the longer diameter measures 12 miles and is roughly parallel to the coast; the average width is 5 miles. Aransas River enters its western corner, Copano Creek the northern corner. A circular lake, Mission Bay, lies on the landward (northwest) side. This very shallow body of water, fed by Mission River, is connected with Copano Bay by two narrow openings. On the seaward (southeast) side Copano Bay is separated from Aransas Bay by Live Oak Peninsula, a broad low area. The southern corner of Copano Bay is extended southwestward as Port Bay, a narrow body of shallow water that ends in a broad marsh.

A dredge haul made near the center of the northeast end of Copano Bay on a mud bottom under 6 feet of water (Sta. 13) brought up balls of muddy sand and a few oyster shells. Dried samples of the mud are gray to nearly black, finely speckled with the white shells of Foraminifera and encrusted with crystals of selenite that formed during the drying process. The sand is composed of angular grains of clear quartz averaging 0.1 mm in diameter.

Washing and flotation produced a rich cencentrate of Foraminifera. Like most closed-bay assemblages, this assemblage is dominated by three genera: *Rotalia, Elphidium* (3 species), and *Nonion.* Also present are a few specimens of *Ammobaculites,* rare specimens of *Miliammina,* and two genera, *Buliminella* and *Bolivina,* not found in nearby closed bays.

A dredge haul in the west-central part of the bay between two of the projecting transverse reefs (Fig. 2) dragged dark-gray mud under 7 feet of water (Sta. 14). The haul was poor, consisting of a few dead shells, mostly of oysters, together with a live jellyfish and a crab. Washing of the clay yielded a few grains of quartz sand, a few valves of ostracodes, and a fair assemblage of Foraminifera, chiefly Rotalias with some *Elphidium* and *Nonion.*

A few living mollusks and crustacea were dredged from muddy sand and weeds under 1 to 3 feet of water on the northeast side of the opening connecting Copano Bay with Aransas Bay. Commonest of the live shells were *Mulinia lateralis* (small), a few live *Ensis* (likewise small), and one *Mitrella lunata. Bittium* and a few other species of small mollusks were represented by rare empty shells.

A haul was made with a hand dredge in 3 feet of water 100 feet off the northeast end of the bridge that crosses the mouth of Copano Bay. Several shells of oysters and other pelecypods were obtained. None except the abundant *Mulinia* appeared to be alive; the assemblage may in large part represent fill.

A series of six bottom samples was collected across the mouth of Copano Bay (Fig. 2). A brief summary of the lithologic and faunal features of these samples is included in the table below.

Station No.	Depth	Lithology	Fauna		Remarks
15	3′ 9″	Gray sandy mud with fragments of oyster shell; considerable selenite in dried sample.	*Elphidium* *Rotalia* *Nonion* *Bolivina*	A A A R	Very rich in Foraminifera.
16	3′ 4″	Gray muddy sand with shell (chiefly worn and riddled fragments of small oysters).	Very similar to No. 15 above.		Few small mollusks (mostly worn shells) with barnacles, few ostracodes and crab fragments.
17	9′	Soft, waxy, gray mud with a few grains of fine sand and bits of shell.	*Ammobaculites* *Rotalia* *Nonion*	F A R	No *Elphidium* present.
18	6′ 8″	Waxy, gray mud with small amount of sand and numerous oyster shells; much selenite in dried sample.	Similar to No. 15 above Foraminifera less abundant.		Few worn mollusks and rare ostracodes with plates of large barnacles; few Bryozoa and fragments of crabs; one marine diatom.
19	6′ 5″	Gray, muddy sand with scattered pieces of shell; opaque twinned rounded plates of gypsum.	*Elphidium* *Rotalia* *Nonion* *Bolivina* *Buliminella*	A A A R R	Very rich in Foraminifera; some oysters, ostracodes, and barnacles.
20	3′ 6″	Hard shell bottom; small amount of muddy sand.	Similar to No. 15 above with rare *Ammobaculites* and abundant *Quinqueloculina.*		Oyster-shell fragments with specimens of each of a dozen species of small mollusks; few Bryozoa, barnacles, and serpulid tubes.

Lower San Antonio Bay

In the northeast corner of San Antonio Bay a dredge haul was made south of Mosquito Point in a tight muddy sand under 4 feet of water (Sta. 21). The sand is very fine, only the largest grains exceeding 0.1 mm in diameter. The grains are angular to subangular and consist of clear quartz; they are accompanied by plates of selenite. Living mollusks including a few Mulinias and razor clams were taken and associated with was the small foraminiferal assemblage that characterizes the closed bays.

A dredge haul in the east-central part of the bay was in muddy sand in 5 feet of water (Sta. 22). Razor clams and shrimp were the only living large organisms recovered, but washing and floating of a sample yielded a rich foraminiferal concentrate. Washed samples are similar to the sands from the northwest corner of the bay.

About 1½ miles to the south in the southeast quarter of the bay a run was made in muddy sand under 6 feet of water (Sta. 23). The bottom was fairly hard, and the recovery consisted mostly of live fish and shrimp. One shell encountered for the first time was *Barnea costata.* On the single valve was a living *Crepidula convexa* encrusted with algae. The assemblage of Foraminifera was much like that to the north and in the other closed bays. The sand is very fine and similar to that obtained to the north and west in the bay; partially opaque twinned plates of gypsum are present.

In the south-central part of San Antonio Bay a dredge run was made on the bottom of the intracoastal canal at a depth of 13 feet (Sta. 24). The dredge brought up dark mud that could be washed through a sieve only with difficulty. The unscreened material dried to a nongritty, almost black waxy clay with many plates of clear selenite. Foraminifera were present in fair numbers.

A run close to shore on the western side of the bay was made in 2 feet of water over a hard bottom composed of clean sand (Sta. 25). The fauna was poor: only a few living Rangias, many shells of *Ensis,* and a meager development of Foraminifera. The sand is free of clay and silt but contains scattered bits of shell, mostly unidentifiable. The sand grains reach a maximum diameter of 0.2 mm and are mostly clear quartz ranging from sharply angular to well rounded.

Three dredge hauls were made in the southwest corner of San Antonio Bay—in the pocketlike extension that leads to Mesquite Bay. The first of these was near Mustang Slough (Sta. 26). The dredging was begun in sand in 4 feet of water close to the edge of a channel and continued into the channel in water several feet deeper. The only large mollusk recovered alive was *Lucina pectinata.* Foraminifera and ostracodes are present in small numbers, *Rotalia* is the most common genus; shells of *Elphidium* (2 species), *Nonion,* and *Ammobaculites* are rare. The sand carries small amounts of clay and scattered bits of shell. It is mostly fine, but grains up to 0.35 mm in diameter are present. Most of the grains are angular or subangular, but a few are fairly well rounded.

A second haul in the southeast corner was made about 1,500 feet off Matagorda Island (Sta. 27). The run was over a muddy sand under 4 to 5 feet of water. No large mollusks were recovered—either dead or alive. The foraminiferal assemblage proved to be poorer than any encountered elsewhere in the bay or anywhere in the closed bays. A few specimens of *Rotalia* with rare examples of two other genera were obtained by washing and floating. The sand is fine and is very similar to that found across the bay near Mustang Slough (Sta. 26).

A haul was made in the extreme southwestern tip of the bay close to an artifically deepened channel that cuts the islands lying between San Antonio Bay and Mesquite Bay (Sta. 28). Here 4 feet of water overlies greenish-gray fine, muddy sand mixed with a few shells of oysters (mostly small), *Mytilus*, and *Mulinia*. Washing and floating yielded a good assemblage of Foraminifera and ostracodes.

Mesquite Bay

Mesquite Bay is a subquadrate but somewhat irregular body of water measuring 4 to 5 miles in diameter. Its northwest corner is produced as a subcircular lobe 1½ miles in diameter (Fig. 2). The Belden Dugout—a part of the Intracoastal Waterway—extends through the main bay and the northwest lobe, but at the time the present study was carried out this section of the waterway had not been maintained and depths were uncertain. Maximum depths in the bay itself run up to 5 feet, that of the northwest lobe only to 4 feet. Linear islands and reefs almost shut off Mesquite Bay from San Antonio Bay to the northeast and Aransas Bay to the southwest. Cedar Bayou, a shallow and somewhat intermittent channel, connects Mesquite Bay with the open Gulf. Two dredge hauls were made in the main bay, one in the lobe to the northwest, and two near the mouth of Cedar Bayou.

Dredging in the north-central part of the bay north of the line of the Belden Dugout in 4 feet of water (Sta. 29) yielded muddy sand carrying many fine shell fragments. The sand is similar to that of the other closed bays—composed mostly of poorly sorted angular to fairly well rounded grains of clear quartz, the largest of which measure 0.3 mm. The dried sample contained much selenite, and many of the plates are twinned. Washing revealed a few very small shells of oysters, *Mytilus*, and ostracodes, some of the last named having both valves. Foraminifera are abundant and the assemblage includes the three common closed-bay genera and two others.

Another dredge haul north of the Belden Dugout (Sta. 30) in the northwest corner of the main bay 1½ miles southwest of Sta. 29 proved similar in all important features. Like the last, it was dredged in 4 feet of water and consisted of muddy sand with small fragments of shell. No ostracodes or identifiable mollusks were found.

A dredge haul in the western extension of Mesquite Bay on the northwest side of the dredged channel (Sta. 31) was made in dark sandy mud under 4 feet of water. A few bits of shell but no identifiable mollusks were found. The assemblage of genera and species of Foraminifera was similar to assemblages collected elsewhere in the bay. The associated sand was very fine, the grains averaging less than 0.2 mm in diameter.

The dredge was lowered in 4 feet of water over muddy sand on the southern side of Mesquite Bay about 1,000 feet off the marshy point lying west of the entrance to Cedar Bayou (Sta. 32). It picked up a crab and a few shrimp but no large shells of any kind. The washed sand was very fine, averaging less than 0.2 mm in diameter. Associated with the sand were a few very small shells of oysters and numerous twinned plates of selenite. The assemblage of Foraminifera conisted of the three genera commonly found in the closed bays and rare examples of *Miliammina*.

A dredge haul was made near the mouth of Cedar Bayou in the section that has been modified by excavation (Sta. 33). At a depth of 4½ feet in soft, brownish-gray mud, the dredge picked up a lot of dead wood, a single valve of *Tagelus gibbus*, and very little else. In the residue of the washed mud was a very small fraction of very

fine quartz sand (0.1 mm average), elliptical twinned plates of selenite 0.5 mm or more in diameter, and flakes of mica. Floating yielded six genera of Foraminifera.

Upper Aransas Bay

Aransas Bay, the second largest bay in the area, parallels the coast behind St. Joseph Island for 15 miles. Its width at its upper (northeast) end where it joins with three other bays is 6 miles; to the southwest it narrows toward Lydia Ann Channel and Aransas Pass and is shut off almost completely from Redfish Bay (another polyhaline bay) by a series of narrow marshy islands. Aransas Bay is deeper than any of the bays already considered; depths of 8 or more feet are found over all parts of the bay except in the northeast corner where maximum depths are less than 8 feet. In this shallow area there are numerous oyster reefs.

A dredge haul in the northeast corner near Poverty Reef to the north of the Belden Dugout was made in 5 feet of water over dark gray sandy mud (Sta. 34). No large shells were recovered but the dried mud is speckled with the shells of Foraminifera. The assemblage obtained by washing and floating is similar to that found in Mesquite Bay. The mud also resembles the Mesquite Bay samples lithologically in the mica flakes and abundant gypsum; some of the gypsum is in the form of twinned plates, many of them opaque.

At the northern end of Aransas Bay, a broad marshy peninsula separates St. Charles Bay from the westward extension of Mesquite Bay. A low ridge fringes the shore to form a beach (Sta. 35). It is composed mostly of shell fragments and the material is excavated for use as a road metal. The bay waters near shore are shallow. the bottom covered by clean sand. The sand is fine and well sorted, averaging 0.1 to 0.2 mm, and composed of clear or slightly opaque quartz angular to subangular in shape. A sample collected in 1½ feet of water 350 feet from shore was unusual in that it contained fresh water diatoms and no tests of Foraminifera. A second sample closer to shore yielded a good fauna of Foraminifera including the genera so widely distributed in the closed bay areas. A hand dredge operated from the shore out to 1,000 feet brought in only a few living Mulinias and other small mollusks.

The beach was strewn with a considerable variety of mollusk shells (Table 1) but broken and worn valves of oysters form 90 percent of the deposit. Many of the small shells are worn and bleached examples of species that may be found alive in the lower and more saline parts of the bay. Associated with such shells are small pieces of worn coral *(Astrangia)* and a few rounded and pitted pebbles of friable calcareous sandstone 5 to 15 mm in diameter. Seven species of land shells are also present, many of them in abundance; in addition, many shells of the air-breathing halophile, *Truncatella,* were found, and about a third of the specimens were alive; shells of this genus were also collected in a number of polyhaline bay stations. With *Truncatella* at Station 35 and in the polyhaline bays were those of another halophile, *Melampus.* Fresh, hinged valves of *Ensis minor* were found in great abundance near the middle of the beach.

Beyond the beach the shore rises to a level of 2½ feet above tide. It is made up of dark sandy earth with many large shells in its upper layer. To landward the surface is a crust of shell over mud.

A dredge haul was made in the middle of Aransas Bay east of Fulton (Sta. 36) in 9 feet of water over slick blue mud containing scattered fragments of oyster shell, a number of Nuculanas and other small pelecypods, and shells of *Acteocina.* Two small flounders, a small crab and a number of shrimp were also included. A sample of the mud dried to a dark gray waxy clay speckled with the shells of numerous Foraminifera and containing scattered sand grains and considerable selenite. Washing yielded large numbers of foraminifers of the three genera that appear to be characteristic of the closed bays.

A second run immediately south of the last was in mud in 9 to 9½ feet of water. The assemblage was similar to the last but not so rich.

A hand dredge was used on the western shore of Aransas Bay near Fulton in 1 to 3 feet of water (Sta. 37). The bottom was of fine to medium sand mixed with small amounts of shell and a few well-rounded and pitted pebbles of calcareous sandstone up to 15 mm in diameter. There was a fair variety of small mollusks, and 10 species were taken alive; Foraminifera were notably rare though three genera were represented (Table 1); a few fresh-water diatoms were also found.

Reef Facies

Lower St. Charles Bay

A dredge haul was made near the center of St. Charles Bay slightly more than halfway from bay head to bay mouth (Sta. 38). This part of the bay is only 3 to 4 feet deep but the soft mud bottom is uneven with patches of oysters on it. The living oysters are growing on dead shells and in each clump of oysters there are numerous living specimens of *Mytilus recurvus.* On a single valve of a dead oyster dozens of specimens of *Mytilus* may be bunched between half a dozen small to medium-sized living oysters, the *Mytilus* bound tightly by their byssal threads to the dead shell or to the edges of the living. The assemblage does not form an extensive hard "reef" but may be looked upon as an initial or very early stage in reef development. Sedimentation apparently is not rapid enough to interfere with growth, the food supply seems adequate, and if the condition persists the scattered clumps of shells may coalesce and form a hard continuous bank. Small oysters are cemented to many of the larger specimens of *Mytilus* and many examples of both shells are encrusted with serpulid tubes, bryozoans *(Membranipora)* and, in a few instances, barnacles. Other living attached forms include *Anomia simplex* and *Crepidula plana* in all stages of growth. Washing the mud included between shells yielded living specimens of an *Odostomia, Cerithium* and *Mitrella* with a fair variety of more or less fragmentary shells of other small mollusks; both valves of an ostracode, fragments of crab claws, etc., were also recovered.

A bottom sample collected at the northeast end of the dredge run consisted of dead shells mixed with a small amount of gray sandy clay; when washed and floated, it yielded a rich concentrate of Foraminifera shells and a fair number of delicate ostracode valves. The Foraminifera make up a typical closed bay assemblage: *Elphidium, Nonion,* and *Rotalia,* together with a few specimens of the arenaceous *Ammobaculites.*

Copano Bay

Copano Bay is shallow, averaging only 7 to 8 feet in the deeper parts. It is divided into compartments by a series of shell reefs and banks that in most places are narrow and rise several feet above the floor of the bay. The best-developed structures of this sort resemble the "long reefs" of Matagorda Bay described by Moore (1907), and extend outward from the northwest side of the bay, thus cutting across its longer axis and the main current. Moore explained that the reefs in Matagorda Bay grow "most rapidly toward the strongest current and less rapidly along their sides, where the currents slacken and eddy and where, therefore, the deposit of mud and silt more speedily engulfs the shells and renders them ill adapted to the attachment of spat." This explanation may be applicable to Copano Bay, but it should be noted that only part of the waters that feed the bay enter it at the southwest end of its long axis. The waters contributed by Mission River enter through Mission Lake on the northwest near the middle of the bay's longer axis. Any current set up by these waters would be at right angles to the bay's axis. In addition to the linear reefs that lie athwart the bay there are subcircular and irregular patches. On the east, Copano Bay is joined to Aransas Bay by a channel 2 miles in width. The deeper part of the channel is less than half a mile wide; the remainder is shallow reef (Fig. 2).

In the northeast end of the bay a landing was made on the narrow shell ridge known as Lap Reef (Sta. 39) that extends almost entirely across the entrance to Aransas Bay. This deposit is about 20 feet wide and is dry even at high tide. Ninety percent of the ridge consists of worn pieces of oyster shell, many of which are riddled by boring organisms. In addition to a few other large shells *(Mytilus, Anomia, Crepidula)* is a small fraction of fine material that includes nine species of pelecypods and nearly two dozen species of small gastropods (Table 1). *Mulinia lateralis* is the only abundant pelecypod, and the most abundant of the small gastropods is an *Odostomia,* some specimens of which look very fresh. Delicate shells of *Caecum* and *Littoridina* are likewise fairly numerous.

A bottom sample was collected in 1½ feet of water a few yards west of the exposed reef. It consisted mostly of shell like that of the reef mixed with a small amount of gray muddy sand. Washing and floating yielded the usual three genera of Foraminifera characteristic of closed-bay areas plus a few specimens of *Bolivina.*

A dredge haul was made in 4 feet of water off the south end of Lap Reef (Sta. 40). The hard bottom supported many living oysters and *Mytilus,* mostly small, with the usual attached forms: crepidulas, barnacles, serpulid tubes, and bryozoans together with a few small Foraminifera.

A haul in the central part of the bay north of Smith Channel (Sta. 41) was made in 6 feet of water over a shell bottom that produced a rich assemblage of living reef shells: oysters and *Mytilus* with many encrusting forms such as *Anomia, Crepidula,* barnacles, serpulid tubes, and bryozoans. Many of the oyster shells are bored by *Martesia.* Material washed from the shells contained fine quartz sand, many specimens of *Rotalia,* a few *Elphidium,* rare *Odostomia,* and valves of ostracodes.

Upper Aransas Bay

In the northeast corner of Aransas Bay, many patches of oyster reef are flourishing in 5 to 6 feet of water. These reefs were sampled with oyster tongs and an oyster dredge (Sta. 42). The oysters are encrusted with numerous *Anomia simplex,* serpulid worm tubes, Bryozoa, and barnacles, and their shells are bored by other organisms, including a *Martesia. Mytilus* is present but in small numbers. There are numerous living examples of *Anachis avara,* a species not found alive elsewhere in the closed bays. Washing and floating of the sandy, greenish-gray mud clinging to the oyster shells yielded a rich assemblage of Foraminifera totaling 9 genera and 15 species.

Polyhaline Bays

As shown in Figure 2, the lower part of Aransas Bay and Redfish Bay are closely connected with the waters of the open Gulf through channels leading to Aransas Pass. As a result, their waters have salinities up to 25 o/oo and their faunas contain many forms that are not found living in the less saline waters of the closed bays.

Lower Aransas Bay

A dredge run in the middle of Aransas Bay off Rockport was made in mud under 12 feet of water (Sta. 43). The fauna was similar to that obtained immediately to the north, but living specimens of *Pandora* were found in abundance for the first time and living Arcas and Nuculanas were fairly common. In addition, there were the dead shells of a number of mollusks that live in great abundance in the lower parts of the bay. For these reasons the assemblage is placed in the polyhaline-bay facies rather than with the assemblages from the closed bays (Fig. 2 and Table 1). The mud dried to a tough gray, slightly sandy clay with many Foraminifera, a few marine diatoms, considerable selenite, and a few flakes of mica.

At Rockport, on the western shore of Aransas Bay, the pier is built on a rock jetty (Sta. 44). On these rocks live many limpets *(Siphonaria naufragum), Littorina ziczac,* and *Mytilus.* Many of the limpets and mussels bear barnacles, some of which are half as large as the supporting shell. The tubes of serpulid worms also encrust the shells.

Three-quarters of a mile southwest of the edge of Rockport (Sta. 45) the bottom is sandy, includes broken shells, and shelves off to a depth of 4 feet at a distance of 1,000 feet from shore. Scattered oysters of fairly large size occur and a few specimens of the sand dollar, *Mellita quinquiesperforata.* Also alive are *Nassarius vibex, Mulinia lateralis,* and numerous Foraminifera. Most of the Foraminifera probably were alive but among them was a single *Gümbelina striata* Ehrenberg, a species widely reported from the Cretaceous of Texas. The nearest outcrops from which this specimen may have been derived are more than 50 miles away.

A mile southwest of Rockport the shore of the bay is a rampart of bedded shell that rises 6 feet above tide and extends landward as much as 150 feet.

Two miles south of Rockport (Sta. 46) a short run was made in 10 feet of water about a mile off shore. The northern end of the run was in muddy sand, the southern end in a mixture of mud and shell with small amounts of sand. The living fauna

was richer and more varied than that dredged anywhere in the closed bay areas. Most of the shells were molluscan but with them were corals, serpent stars (small, mud-loving forms), many foraminifers, and a few marine diatoms. Spines of regular sea urchins, fish bone, and the tooth of a small shark were also recovered. Though this locality is 11 miles from the Gulf; it is directly connected by fairly deep water and the salinity at the bottom is between 16 o/oo and 20 o/00.

Dredging in 7 feet of water off Turtle Bayou (Sta. 47) was in hard, clean, white sand containing mostly fragmentary shells of a number of small mollusks along with a few Foraminifera, and a few fresh- or brackish-water diatoms. The sand is angular to subangular, of clear quartz and well sorted, the grains averaging 0.1 to 0.15 mm in diameter.

At the southeast end of Aransas Bay a dredge haul was made west of Mud Island (Sta. 48). The bottom under 7 feet of water was covered with shell mixed with a small amount of muddy sand. The molluscan fauna is rich and varied, comparable in its main features to that found at Station 47, which is 2½ miles to the north. The foraminiferal assemblage is likewise similar and contains one genus, *Triloculina*, not found elsewhere in Aransas Bay nor in any of the closed bays.

Redfish Bay

Redfish Bay is a small triangular body of water whose broad base extends parallel to the coast. Its northeast end overlaps the lower part of Aransas Bay, its southwest end bears a similar relation to Corpus Christi Bay, but Redfish Bay is almost completely shut off from these two large bays by shoals and elongate, low-lying islands. The broad expanse of Harbor Island at the apex of the triangle separates Redfish Bay from Aransas Pass, but a narrow channel with a minimum depth of 4 feet has been dredged across it. This channel has since been deepened to 9 feet.

A total of 22 dredge hauls and samples were collected in Redfish Bay, many of them in the southeast half of the bay between Ransom Island and the channel that leads eastward from the town of Aransas Pass.

A hand dredge was used in the northeast half of the bay starting at a point 3½ miles northeast of the town of Aransas Pass and extending out 1,000 feet from shore (Sta. 49). The shore is marshy; the bottom is mud and shell with a coating of dead tapeweed. A fair crop of live weed supports large numbers of small gastropods—chiefly *Cerithium variabile.*

From the southern edge of the town of Aransas Pass a causeway leads southwest to an unnamed island about a mile from shore, follows this island southeast and south for another mile, then over a second stretch of causeway to Ransom Island. Collections were made at several points along the causeway and all around the shore of the island.

A quarter of a mile from the mainland the floor of sandy mud and weed (Sta. 50) on the northeast side of the causeway is under 1 to 1½ feet of water. Dredging through the weeds brought up living specimens of *Bittium* and *Anomalocardia*, but more specimens of these species and other mollusks including *Chione cancellata* were obtained by dredging both weed and top layer of soft mud. Many of the *Cerithium* shells bear the shells of *Crepidula.* Though the sample was sieved in the field, many small mollusks along with some Foraminifera and ostracodes were recovered (Table 1).

A similar but somewhat less varied fauna is found on the southwest side of the causeway. *Bittium* is very abudant in some places and Neritinas also, especially in weedy areas where the growth is not very rank.

At a point nearly half a mile from the mainland, (Sta. 51) on the northeast side of the causeway, the weed-covered sand bottom under 1½ feet of water yielded many living examples of *Abra, Anomalocardia,* and *Cerithium,* with a few examples of *Chione, Bittium,* and *Nassarius vibex.* Minute shells of *Crepidula convexa* occur in great numbers, and two examples of *Bulla* were taken, one of them alive. Foraminifera were not abundant.

At most points near the Ransom Island causeway *Abra* is rare, but almost everywhere in the weed-covered areas *Corbula* and *Bittium* are to be found. The bottom in most places is sandy with clay or blue muck below. A few Foraminifera are found in the sand. In water more than 18 inches deep the bottom is very soft.

In the southwest half of Redfish Bay, collections were made at several points in the shallow waters that fringe the marshy shore. At a point 2 miles southwest of the end of the causeway leading to Ransom Island and 20 to 25 yards off shore (Sta. 52), the water is only a few inches deep. Weeds growing on the bottom are awash and the water becomes very warm during the day. On the weeds are countless numbers of living Cerithideas, Neritinas, and Cerithiums. The Cerithideas are the most abundant—more than 100 can be picked up within arm's reach. All seem to be thriving in the hot shallow water. In the bottom mud are a few small pelecypods—*Anomalocardia* and *Tellina.* This same assemblage continues off shore for over 600 feet where the water is still only about 6 inches deep. The gray muddy bottom sand is rich in Foraminifera and ostracodes. In addition to samples already mentioned, washed samples yielded a considerable variety of mollusk shells, most of them small forms (Table 1).

Ransom Island is shaped like an isosceles triangle. Its broad base three-quarters of a mile long extends northeast and faces the lower part of Redfish Bay. The shore is bordered by a mat of dead weed, and the muddy bottom beyond is strewn with scattered oysters. On the sides of the triangle facing Corpus Christi Bay and its northeast extension the water is deeper, circulation is better, and salinity higher. As a consequence mollusks are found in much greater variety and abundance. Foraminifera are also abundant. For long stretches the shore is a bank of shells and sand. Many of the fine particles in this deposit are well-rounded bits of shell, and the numerous small gastropod shells present have angular to subangular sand grains wedged into their apertures. Foraminifera are not numerous. The deposit is bedded above tide for a foot or more and is one of the richest shell deposits seen anywhere in the bays. All shells collected in the immediate vicinity of Ransom Island are referred to Station 53 of Figure 2 and Table 1.

Bittium and other small living gastropods were dredged near shore from weeds growing on a soft mud bottom in 3 feet of water, but no living mollusks were found around the small islands near Ransom; the bottom in these barren areas is paved with coarse shell.

About half a mile west of Ransom Island and immediately south of the line of islands that lie between Ransom and Dagger (Sta. 54)—and, therefore, technically in Corpus Christi Bay—the waters near the shore are 2 to 3 feet deep, and the bottom of muddy sand and shell supports a thick growth of tape grass and *Ruppia maritima.*

Living shells of *Pecten irradians amplicostatus* are numerous in this growth. Locally there are two or three to the square yard. They swim about actively, audibly snapping their valves in the process. When they are at rest the colored left valve is usually uppermost. It is this valve that bears most of the encrusting organisms—Crepidulas, calcareous and soft algae, barnacles, and serpulid worm tubes. The Crepidulas are fitted snugly into the deep grooves of the shell or are piled one upon another—a total of 80 or more on a single valve.

Living shells of *Chione cancellata* are second only to the pectens in abundance. They and a rare specimen of *Lucina* were found lying free on the bottom.

Passes

The narrow barrier that parallels the coast for a distance of 215 miles from the mouth of the Colorado southwestward to the Rio Grande at the Mexican border is broken in only half a dozen places by deep passes or shallow bayous. One pass and one bayou were examined during the present study: Aransas Pass, a deep opening from Aransas Bay that separates Mustang and St. Joseph Islands, and Cedar Bayou, which separates St. Joseph Island from Matagorda Island. Cedar Bayou is narrow and shallow, and periodically it is blocked off completely by sand. A few observations and collections were likewise made near the mouth of the Colorado River, a major stream; part of the river waters now reach the Gulf through a flood discharge channel extending for 7 miles from the city of Matagorda across Matagorda Peninsula.

Aransas Pass

Aransas Pass connects three open bays with the Gulf of Mexico (Fig. 2). The broadest channel (Lydia Ann Channel) leads northward from the Pass to Aransas Bay; the second, a narrow and shallow artificial channel crosses Harbor Island and leads to the town of Aransas Pass on Redfish Bay; a third channel, deepened by dredging, leads westward to Corpus Christi Bay. The Pass itself and all of its channels have been modified by dredging and other engineering operations, which were begun in 1869. In that year a light cribwork jetty was built by the citizens of Rockport and Corpus Christi. It extended from St. Joseph Island across a secondary channel for a distance of 600 feet. After this structure was built, the secondary channel shoaled 2 feet and the main channel was deepened by an equal amount, but wave action and the borings of *Teredo* destroyed the crib (Report of the Chief of Engineers, 1915). Work by the United States was started in 1879 and has continued at intervals to the present. It has included the construction of stone jetties, dikes, and groins, dredging, and removal of obstructions. At the time of the present investigations, the mouth of Pass was protected by stone jetties extending far out into the Gulf (Fig. 2). The depth in the Pass was 35 feet below mean low water. Depths in Lydia Ann Channel ranged from 9 to 22 feet. The channel leading to the town of Aransas Pass had had a minimum dept of only 3½ feet, but the Corpus Christi ship channel was maintained at a depth of 32 feet. Since Lydia Ann Channel was the broadest and least modified channel, dredging operations were carried on there to supplement collections made along the banks of the main pass and off the mouth of the pass in the open Gulf.

A dredge haul was made at the northern end of Lydia Ann Channel southwest of Mud Island (Sta. 55). The dredge was pulled for a distance of about 400 feet over

a bottom of mixed shell and muddy sand under 9½ feet of water. The sand, like that of the bays, is composed almost entirely of fine grains of clear quartz, the largest, 0.25 mm in maximum diameter; most of the grains are angular, but some are subangular and a few are well rounded. Clusters of gypsum crystals are fairly abundant.

In addition to the dead shells of the bottom (Table 1) a number of living mollusks were brought up by the dredge. The most abundant of these is *Chione cancellata* (some with live oysters attached), small Cardiums, Pectens, Arcas, and large shells of *Anomia; Polinices duplicata* and *Crepidula plana* were the only living gastropods recovered. The foraminiferal fauna was fairly rich, including one genus, *Guttulina,* not found in any of the closed-bay samples.

Near the north end of Murray Shoal (Sta. 56) a dredge haul in clean sand and shell under 7½ feet of water brought up a rich and varied molluscan fauna. Among the bivalves the commonest forms were *Chione, Cardium, Arca,* and *Anomia;* among the gastropods, *Polinices* and *Crepidula.* A scaphopod, *Dentalium,* is abundant and some of the shells were alive; a small chiton *(Ischnochiton)* was also alive when collected. Other living forms included a starfish, abundant Foraminifera, and rare marine diatoms.

In Lydia Ann Channel off the north end of Lydia Ann Island (Sta. 57) a sand and shell bottom was found in 25 feet of water. The dredge brought up a heavy load of small oysters and other bivalves, many of them alive, along with a great variety of other forms including micromollusca, foraminifers, and ostracodes.

A dredge haul (Sta. 58) was made in Lydia Ann Channel about 1¼ miles south of Station 57 and 2 miles from the head of the main pass. The haul, made in 18½ feet of water, brought up sand and mud containing a great variety of living and dead mollusks, mostly pelecypods but some gastropods, among them, *Oliva sayana,* a species not found alive in any of the bays. Also recovered were fragments of echinoids, many small corals *(Astrangia),* and the usual encrusting organisms. No sample of the fine material was saved, but Foraminifera were noted in some of the fine grains adhering to the washed shells.

In Aransas Channel between Hog Island and Harbor Island (Sta. 59) large specimens of *Thais* were found alive on rocks immediately below low tide level. The heavy shells are thickly encrusted with barnacles, bryozoans, and serpulid tubes, and a few corals *(Astrangia),* small oysters, Crepidulas, and *Mytilus.* Dead shells of *Thais, Busycon,* and *Polinices* occur in large numbers, serving as homes for hermit crabs.

No specimens of *Thais* were found on rocks at a point half a mile to the southeast of Station 59 and the dredge let down near this point brought up only soft mud covered with a veneer of shell (much of the shell was probably dredged up in constructing the causeway that parallels the channel).

The greenish-gray muddy sand in Aransas Channel was sampled near the northwest border of Harbor Island (Sta. 60). At this point the channel was 5 feet deep. The material contained a few fragmentary remains of mollusks and crabs with a meager assemblage of foraminifers. The sand is similar to that found in the bays, being composed of fine, angular to well-rounded grains of clear quartz up to 0.25 mm in greatest diameter; present also are opaque, twinned crystals of gypsum.

In the main pass (Sta. 61) the blocks of rock used for riprap and dock piling yielded large numbers of *Thais* and *Siphonaria.* The former are thickly encrusted with small

oysters, barnacles, bryozoans, and serpulid worms; small shells of *Mytilus* are commonly found growing inside the shells of dead barnacles.

Cedar Bayou

Cedar Bayou is a narrow pass with a maximum recorded depth of 13 feet. Near its junction with the Gulf, the depth is only 4 feet. A dredge haul was made close to the entrance to the Gulf in 2 feet of water on a sand bottom (Sta. 62). No mollusks other than single specimens of *Arca campechiensis* and *Arca transversa* were taken alive, though the dredge brough up numerous shells of *Tagelus* along with a few examples of half a dozen other bivalves, a fragment of *Oliva,* crab claw, echinoid fragments, seeds, and bits of wood. A bottom sample from the same locality showed the sand to be clean, with a high percentage of well-rounded quartz grains. A meager fauna of Foraminifera was recovered.

Open Gulf

The floor of the open Gulf in the area under consideration is comparable in flatness to coastal lands that border it. Dredging operations were not extensive and, as shown in Figure 2, all were made within a few miles of Aransas Pass. One haul was made immediately off the mouth of the Pass, others off the beaches on either side, four off St. Joseph Island at distances between 2 and 4 miles offshore. The greatest depth encountered was 48 feet. Bottom samples taken near shore were mostly clean sand, those farther out muddy sand.

Near Shore

A bottom sample was collected in 9 feet of water 300 yards offshore and about 1½ miles north of the entrance to Aransas Pass (Sta. 63, Fig. 2). The material was clean sand with scattered fragments of shell and a fair assemblage of foraminifers; a single living sand dollar and two starfish were also recovered. After an intensive concentration of material from this station, K. E. Lohman recovered a flora of diatoms numbering 17 species, but none of them were present in abundance (Table 2). The flora, as Mr. Lohman pointed out, is dominantly marine in character; all but two species occur only in marine waters. The two exceptions, *Rhaphoneis surirella* and *Rhopalodia gibberula* var. *baltica,* are known from both marine and brackish water.

A long haul parallel to the shore was made 3 miles north of the entrance to Aransas Pass (Sta. 64); the run was 500 yards off shore in 8 to 10 feet of water. The dredge brought up living Olivas, Arcas, sand dollars, starfish, and hermit crabs along with the shells of about 40 species of mollusks (Table 1), including small oyster shells, mostly the unattached upper valves.

A haul 1,000 yards offshore 2 miles southwest of Aransas Pass in 17 feet of water yielded dozens of living starfish *(Astropecten marginatus),* a few sand dollars *(Mellita quinquiesperforata),* and *Squilla* but no living mollusks other than three Arcas *(A. transversa* and *A. campechiensis)* and a single *Oliva.* Another haul southeast of the Pass and a mile off shore gave a poor recovery—a few *Thais* shells and living examples of *Renilla,* an alcyonarian.

A dredge haul off the mouth of Aransas Pass and in the area to the south (Sta. 65) was made in sand under 24 feet of water. The most abundant living forms were sand

dollars along with Arcas and a few other mollusks *(Oliva, Busycon)*, large starfish *(Astropecten articulatus valencienni)*, and crabs. The sand is fine, with a few grains measuring up to 0.35 mm, and is composed mostly of angular to rounded grains of clear quartz. Foraminifera were rare.

A sample of brown sandy mud was dredged about three quarters of a mile northeast of the entrance to Aransas Pass in 36 feet of water (Sta. 66). No mollusks were recovered, and Foraminifera and diatoms were rare.

Offshore

The dredge was dragged northeast of the entrance to Aransas Pass and 3 miles offshore (Sta. 67) in 41 feet of water over muddy sand. Only specimens of *Renilla*, a single *Arca transversa*, a fragment of a boring clam, and a few Foraminifera were recovered.

Dredging was continued to the east-northeast for about a mile, ending in 48 feet of water over brown muddy sand (Sta. 68). The sand contained scattered subcircular twinned plates of partially opaque gypsum measuring 1 to 1.5 mm in diameter. No living organisms except *Renilla* were recovered.

A dredge haul at Station 69, northeast of Station 68, started at a point 3 miles offshore and continued seaward for about half a mile. In the rich fauna of living gastropods recovered, *Anachis obesa* and *Nassarius acuta* were the most abundant; associated with them were many specimens of *Arca transversa* and *Arca campechiensis*. The assemblage was unusual for all of the shells are small and, in some species like the abundant *Cantharus*, are all immature. With the shells, the dredge brought up a number of small crabs and a few specimens of *Renilla*.

Dredging was continued seaward (Sta. 70) to a point nearly 4½ miles from shore, ending in 45 feet of water over brown muddy sand. This was a poor haul, for the dredge brought up only a few small gastropods and some examples of *Renilla*. The sand contained small plates of opaque gypsum and a few marine diatoms but no Foraminifera. This station not entered in Table 1.

Beaches

Sand beaches fringe the Texas coast almost without interruption, and for long stretches they are unvarying in form and composition. Near the mouths of large streams, such as the Colorado, there is an admixture of driftwood, land shells, and other materials from the land. In other places, such as the "Big shell banks" of Padre Island, the sand may be replaced by much coarser material, but such conditions are local.

Shells of mollusks and the hard parts of many other invertebrates are found in abundance on Gulf beaches, but these sandy areas with their active surf are ideal homes only for burrowers such as *Donax*. These clams, by countless thousands, burrow in the sand exposed by each retreating wave; but very few other living forms are to be seen. Crabs scuttle in the low surf, and an occasional living starfish may be temporarily stranded between waves. Many mollusks (*Cardium, Anatina, Dosinia, Atrina, Oliva*, etc.), of course, live in or on the sands that extend outward from the shore, and their dead shells litter the beach. The beach fauna differs in another way from many of the facies previously described because deposition is not continuous. Shells

and other organic material may remain upon the beach for an appreciable time if carried to a high level by storm waves or an unusually high tide; otherwise they may be slowly ground up to form sand and coarser material and may later be carried out to deeper water. Beach shells may be buried at least temporarily under dry sands moved by northerly winds. Day-to-day observations on some of the beaches revealed a considerable variation in roughness that pointed to a reworking of the surface sands by waves and currents. As a corollary, the number of unbroken shells on the beach likewise varies, owing, no doubt, to the same shifting tides and currents. The beach assemblage is an ephemeral mixture consisting almost entirely of dead shells. With a subsiding coast or a rising sea level the beach sands and their shells could be buried and preserved, possibly to be recognized at a later date in drill cores of cuttings. For this reason, the assemblage is briefly described as a separate facies.

Fairly varied molluscan fauna was collected on Matagorda Island's beach near the entrance to Cedar Bayou (Fig. 2, Sta. 71). Included were a number of forms that were rare or entirely absent in the passes and the bays: *Navicula, Periploma, Anatina, Atrina, Sinum, Architectonica, Semicassis, Tonna.* Starfish and many specimens of the sand dollar, *Mellita,* were found. The Mellitas were all dead, the tests serving as basis for the attachment of long strands of the gorgonian, *Leptogorgia.* Land shells were found in great numbers and variety, along with many twigs and small branches of wood. Ostracode valves and the shells of foraminifers were abundant in the sand. Thin-shelled mollusks, such as *Anatina* and *Tonna,* were rarely found complete.

Collections were made from the seaward beach on Mustang Island on a number of occasions. The lower part of the beach is of hard sand at the water's edge, and in the zone washed by the low surf there are large numbers of living *Donax.* Many of these active clams burrow quickly into the sand as each wave recedes but others do not; even those that burrow can be quickly recovered by hand. The burrowers enter the sand rapidly in a series of jerky movements, the anterior pointed end disappearing first.

Among the common beach shells, the largest are Arcas and Dosinias, the valves of many of these forms still hinged together. The dead shells of *Donax,* however, appear to be as abundant as all other shells on the beach put together; and locally, as near the southwest end of Mustang Beach, the *Donax* literally form a beach pavement.

Among the most fragile shells to be found on the beach are the thin purple coils of the pelagic snail *Janthina.* These shells may be so fresh that some of the soft parts are still attached, but the shell is so delicate that even in such condition it is rarely complete. The writer found one other object comparable in fragility to *Janthina*—the unbroken egg of a bird[6] mixed with shells on the beach close to the water's edge.

The assemblage of beach shells shows some variation from one end of the island to the other. For example, at the southwest end, sand dollars and the clam *Cardita* were found much more abundantly than elsewhere, but the big Arcas and the Dosinias that characterize the northeast end of the island were absent.

Among the rare shells occurring on the beach are those of *Spirula,* limpets, and oysters. The tests of Foraminifera are abundant in the beach sand. *Elphidium, Massilina,* and *Quinqueloculina* are the most numerous, with a comparatively few specimens of *Rotalia, Cibicides, Triloculina,* and *Guttulina.*

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[6]Unfortunately this specimen was broken in transit; Dr. Herbert Friedmann, who examined the crushed shell, thought it possibly an egg of one of the rails.

The northern half of the seaward beach of Padre Island was briefly examined. For long stretches this beach resembles that of Mustang Island to the northeast, but starting at a point about 50 miles from the northern end of the island and extending southward for a dozen miles are the "big shell banks." Along this stretch, on the lower beach near the water's edge, there are very few shells of any kind, but a bank paved with large shells lies to landward. The number of abundant species is not high: *Venus, Cardium, Arca,* and *Echinochama,* with a few shells of *Dosinia, Pecten, Crassostrea, Modiolus,* and *Donax.* Locally on the landward side of the shell banks is a belt of active irregularly-shaped sand dunes. Patches of coarse sand in the dunes are made up largely of well-rounded fragments of marine shells together with some more or less fragmentary land shells; an occasional large and much worn marine shell may be found at least a mile inland.

Crassostrea virginica occurs as single valves and as clumps of valves. Some of the single valves measure 5½ inches in length, and the clumps are even larger. These reef-building oysters are estuarine animals that require a salinity well below that of normal sea water for optimum development. It is surprising to find their shells on a beach many miles from the nearest pass and to seaward of a lagoon that at all times is too saline for oyster growth, An old dead reef has been reported off this Island (Gunter, G., written communication). Conceivably these oysters lived in brackish waters at a time when the Padre Island barrier lay farther out in the Gulf or, since they are well worn, it may be that they were carried along the beach by longshore currents. It is known that under exceptional conditions reef-building oysters are found alive in the waters of the open Gulf. Cary (1906) has reported such conditions off Vermilion and Iberia Parishes in Louisiana where comparatively fresh waters from Vermilion Bay issue through Southwest Pass and from Atchafalaya River. According to Cary, the salinity of the waters in this part of the Gulf is so lowered that oysters form reefs 2½ miles off shore. Gunter (1951) has recently reviewed the distribution and growth habits of the three species of oysters known from the Gulf.

Among the shells that may be found on Padre Island are the following:

Arca incongrua Say
Navicula umbonata (Lamarck)
Eontia ponderosa (Say)
Atrina species
Crassostrea virginica (Gmelin)
Spondylus species
Pecten irradians amplicostatus Dall
Modiolus tulipus Linnaeus
Cardita floridana Conrad
Echinochama species
Lucina (Anadontia) species
Cardium robustum Solander
Dosinia discus Reeve
Chione cancellata Linnaeus
Chione latilirata (Conrad)
Venus mercenaria Linnaeus
Petricola pholadiformis Lamarck
Tellina alternata Say
Donax species
Barnea costata Linnaeus
Polinices duplicatus Say
Sinum perspectivum Say
Semicassis inflata Shaw
Tonna species
Thais floridana Conrad
Busycon contrarium (Conrad)
Busycon pyrum Dillwyn
Oliva sayana Ravenel

The Colorado River now flows through newly made dry land directly to the Gulf, and the major part of its load is dropped there instead of in the coastal bays. When

examined in late June of 1940 its flood waters were heavy with reddish-brown sediment and there was much driftwood. On the beach near the river's mouth—especially near the upper levels of the beach—the usual marine fauna is mixed with land shells brought down by the stream.

Highly saline lagoon

Laguna Madre

Laguna Madre is a long and narrow coastal bay separated from the Gulf by the even narrower barrier of sand known as Padre Island. In geographic position the Laguna thus resembles several of the open bays that lie to the northeast, but factors other than geographic position make it unique and call for special consideration. The overall length of the Laguna is 130 miles; its width averages only 4 miles. Throughout its length, Padre Island separates it effectively from the Gulf, though at long intervals storm waves may open temporary inlets. At each end of the Laguna there is a narrow permanent connection with the Gulf and, in addition, at the northeast end, a wide shallow opening into Corpus Christi Bay. Several other factors contribute to the unique character of the Laguna: the shoaling to a maximum depth of 9 feet; the extension of the lagoon from a subhumid into a semiarid area where, in general, evaporation is high and rainfall sparse, especially during the summer, and where there are no permanent streams of any size to bring in fresh water. During normal summers the waters of the Laguna become more saline than those of the Gulf; and during prolonged droughts, as Gunter has pointed out (1942), the salinity may increase to three times that of the Gulf waters. At such times all or nearly all of the marine life is exterminated. Between droughts, parts of the Laguna are the most prolific fishing areas in Texas (Hedgpeth, 1947); in general, however, circulation is poor, and since 1860 a large strip in the middle has, for practical purposes, become dry land for it is covered even at the very highest tides by only an inch or two of water (Price and Gunter, 1942).

The regularity of the landward margin of Laguna Madre is broken by a number of indentations and by one large dendritic bay, Baffin's Bay, that joins the Laguna 30 miles southwest of its junction with Corpus Christi Bay. One of the shallow upper arms of Baffin's Bay is known as Laguna Salado, and a series of samples (Fig. 1, Sta. 81–84) were collected near its mid-point (Fig. 1). The visit was made in mid-summer (July 23, 1940), when the shore was a sand flat with a crust of mud mixed with salt crystals. Large areas of the flat (Sta. 83) are literally paved with shells of small bivalves—chiefly *Mulinia* and *Anamalocardia*. All appeared to be fresh, and in many of the Anomalocardias the valves were still attached, but no mollusks were found alive. With the above-mentioned shells were fragments of *Mytilus*, rare specimens of *Acteon* and *Acteocina*, numerous tests of *Elphidium*, *Rotalia*, and *Quinqueloculina*, and rare examples of *Miliolinella*. There were likewise the desiccated bodies of many small fish, along with skeletons of larger forms and many individual bones and scales, many barnacle plates, a few ostracode valves, and fragmentary crustacean remains. The abundant fish remains may in part record deaths due to the severe cold that occurred 6 months prior to the writer's visit (Gunter, 1941a).

Bottom samples collected at a point 165 feet from shore under 2½ feet of water (Sta. 81–82, Fig. 1) consisted of gray muddy sand with scattered shells of small

mollusks *(Anomalocardia, Mytilus, Tagelus, Tellina, Cardium, Acteon)*, barnacles, ostracodes, serpulid tubes, and an assemblage of Foraminifera like the shore fauna but with the addition of *Triloculina*. None of these forms were found alive.

A careful search of the material by Mr. Lohman yielded a small diatom flora: *Mastogloia* cf. *M. brauni, Mastogloia* species, *Navicula* species, *Pinnularia borealis* Ehrenberg, and *Rhopalodia musculus* (Kutzing). This assemblage is a mixture. *Mastogloia brauni* is a brackish-water form, the *Pinnularia* is common in fresh water, and *Rhopalodia musculus* is known from both marine and brackish water. No doubt, as Mr. Lohman suggests, many of these diatoms were introduced from a brackish part of the bay or from a source of fresh water that emptied into it.

The sand grains are of clear quartz, subangular to well rounded and accompanied by small plates of gypsum. Long curved crystals of selenite also occur in the sample, and evidently represent material that crystalized as the sample dried.

At the upper edge of the beach at high tide level there is a wrack assemblage composed mostly of insects, seeds, feathers, fragmentary crustacea, scales, bones, dead fish, and land and marine mollusks, all salt encrusted. The marine shells are mostly small and include *Tagelus, Anomalocardia, Mulinia,* and *Acteon punctostriatus*. The valves of most of the clams are closed and were thus easily floated to the top of the beach. There are also numerous tests of *Rotalia,* a few of *Triloculina* and *Quinqueloculina,* a few barnacle plates, and bits of worm tubes. This is an interesting assemblage and one that could be recognized without difficulty if encountered in a rock section.

No barnacles were found alive on the piles at Carolina Beach on Grullo Bayou (another arm of Baffin's Bay) at a point 4 miles above the Bayou's mouth.

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Foraminifera of the South Texas Coast[1]

By

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ABSTRACT

Foraminifera from the contrasting environments of the nearly fresh waters of the bay-head facies to the more highly saline waters of the bays, passes, and open Gulf of Mexico were studied. A chart shows the distribution of the species. The varying salinity in this area definitely limits the occurrence of certain species. Thirty-two species were found, of which twenty-one are figured.

INTRODUCTION

The samples that form the basis of this study are 54 bottom samples and 8 dredge hauls collected by Harry S. Ladd of the U. S. Geological Survey. For detailed information on location of stations and description and salinity of facies, see Ladd (this volume).

The area is divided into facies as follows: closed bays, polyhaline bays, passes, and open Gulf. In the closed bays three subfacies are recognized: bay-head subfacies, inter-reef subfacies, and reef subfacies.

Although many factors influence the distribution of Foraminifera, salinity seems to be the dominant one.

Salinity data were obtained from Galtsoff, Collier and Hedgpeth.[2]

1. Bay-head facies

With the exception of the rare occurrence of *Miliammina* and *Ammobaculites*, only three genera were found in this facies: *Nonion*, *Elphidium*, and *Rotalia*. The greatest percentage of the samples is made up of the following three forms: *Elphidium gunteri* Cole var. *galvestonensis* Kornfeld, *Rotalia beccarii* (Linné), and *Rotalia beccarii* (Linné) var. *tepida* Cushman.

The salinity here ranges up to 9 parts per 1000, indicating that the above species can adapt themselves to a nearly fresh water environment.

From the study made here, the occurrence of the three genera, *Nonion*, *Elphidium*, and *Rotalia*, together with the absence of Miliolidae and Buliminidae, is indicative of very nearly fresh water.

S. W. Lowman[3] notes that *Rotalia* and *Elphidium* predominate in waters having a salinity of 5 to 15 parts per 1000.

H. D. Hedberg[4] reports *Rotalia beccarii* (Linné) as a brackish-water to marine species that is able to live in waters of low salinity but that is also common in

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[1]Publication authorized by the Director, U. S. Geological Survey.

[2]Galtsoff, P. S. 1931. A survey of oyster bottoms in Texas. Bur. Fish Invest. Rept. VI, pp. 1–30. Collier, Albert and Hedgpeth, Joel W. 1950. An introduction to the hydrography of tidal waters of Texas. Pub. Inst. Mar. Sci., vol. 1, no. 2, pp. 125–194.

[3]Lowman, S. W. 1949. Sedimentary facies in Gulf Coast. Bull. Amer. Assoc. Petr. Geol., vol. 33, no. 12, p. 1953.

[4]Hedberg, H. D. 1934. Some recent and fossil brackish to freshwater Foraminifera. Journ. Pal., vol. 8, no. 4, pp. 474, 475.

definitely marine waters. He also notes that in shallow water it is commonly associated with species of *Elphidium* and *Nonion.*

2. Inter-reef and reef facies

The three genera mentioned above remain prevalent here along with species of the families Miliolidae and Buliminidae.

The following species are present here but do not occur in the bayhead facies:

Ammobaculites dilatatus Cushman and Bronnimann
Quinqueloculina candeiana d'Orbigny
Quinqueloculina costata d'Orbigny
Massilina peruviana (d'Orbigny)
Trochammina inflata (Montagu)
Elphidium incertum (Williamson)
Elphidium morenoi Bermudez
Elphidium translucens Natland
Buliminella elegantissima (d'Orbigny)
Bolivina striatula Cushman
Cibicides concentricus (Cushman)

The appearance of these eleven additional species suggests the second foraminiferal facies. The waters here are brackish and at no locality in this area do the species occur abundantly. It is concluded that these species can live in a brackish-water environment, 9 to 20 parts per 1000, but do not thrive there.

Hada[5] notes that *Buliminella elegantissima* d'Orbigny is among the Foraminifera common to brackish and sea waters.

3. Polyhaline bays, passes, and open gulf

The fauna in these areas comprises a third foraminiferal facies. Specimens of the Miliolidae appear in abundance and with a noticeably greater variety of species.

The following species were not found in the closed bays:

Quinqueloculina bidentata d'Orbigny
Quinqueloculina seminula (Linné)
Quinqueloculina subpoeyana Cushman
Miliolinella circularis (Bornemann)
Massilina annectens Schlumberger
Spiroloculina manifesta Cushman and Todd
Triloculina linneiana d'Orbigny
Triloculina oblonga (Montagu)
Triloculina trigonula (Lamarck)
Guttulina spicaeformis (Roemer) var. *australis* (d'Orbigny)
Elphidium advenum (Cushman)
Discorbis sp.

Here in waters having a salinity in excess of 20 parts per 1000 the family Miliolidae becomes more evident and a greater variety of species is recorded.

In general, it can be concluded that certain species thrive as readily in a nearly fresh water environment as in marine waters, namely:

Nonion pauciloculum Cushman
Elphidium gunteri Cole var. *galvestonensis* Kornfeld
Rotalia beccarii (Linné)
Rotalia beccarii (Linné) var. *tepida* Cushman

Kornfeld[6] in his study of the Gulf area states that there are no marked differences between assemblages of the open coast and those behind the elongated land bodies off the mainland. He reported that the Foraminifera become less abundant in embayments and the arenaceous types tend to prevail over the calcareous types. It is evident from the distribution chart that arenaceous species do not appear particularly noticeable in any of the facies here and their occurrence is sparse in all areas.

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[5]Hada, Yoshine. 1936. Studies on the Foraminifera of brackish waters, I, Hijirippu and Mochirippu Lakes. Zool. Mag., vol. 48, p. 848.

[6]Kornfeld, M. M., 1931. Recent littoral Foraminifera from Texas and Louisiana. Contr. Dept. Geol. Stanford Univ., vol. 1, No. 3, p. 77.

Biological list of species recorded on distribution table

Ammobaculites dilatatus Cushman and Bronnimann.
Ammobaculites salsus Cushman and Bronnimann var. *distinctus* Cushman and Bronnimann
Miliammina fusca (H. B. Brady)
Quinqueloculina bidentata d'Orbigny
Quinqueloculina candeiana d'Orbigny
Quinqueloculina costata d'Orbigny
Quinqueloculina seminula (Linné)
Quinqueloculina subpoeyana Cushman
Miliolinella circularis (Bornemann)
Massilina annectens Schlumberger
Massilina peruviana (d'Orbigny)
Spiroloculina manifesta Cushman and Todd
Triloculina linneiana d'Orbigny
Triloculina oblonga (Montagu)
Triloculina trigonula (Lamarck)
Trochammina inflata (Montagu)
Guttulina spicaeformis (Roemer) var. *australis* (d'Orbigny)
Nonion pauciloculum Cushman
Elphidium advenum (Cushman)
Elphidium articulatum (d'Orbigny)
Elphidium gunteri Cole var. *galvestonensis* Kornfeld
Elphidium incertum (Williamson)
Elphidium morenoi Bermudez
Elphidium poeyanum (d'Orbigny)
Elphidium translucens Natland
Buliminella elegantissima (d'Orbigny)
Bolivina striatula Cushman
Discorbis sp.
Rotalia beccarii (Linné)
Rotalia beccarii (Linné) var. *tepida* Cushman
Cibicides concentricus (Cushman)

Family Lituolidae

Genus Ammobaculites Cushman, 1910

Ammobaculites dilatatus Cushman and Bronnimann

Ammobaculites dilatatus Cushman and Bronnimann, Contr. Cushman Lab. Foram. Res., vol. 24, pt. 2, 1948, p. 39, pl. 7, figs. 10, 11.

Specimens have been compared with paratypes from the Gulf of Paria, Trinidad, B.W.I. They are much smaller but otherwise typical.

Ammobaculites salsus Cushman and Bronnimann var. distinctus Cushman and Bronnimann

Ammobaculites salsus Cushman and Bronnimann var. *distinctus* Cushman and Bronnimann, Contr. Cushman Lab. Foram. Res., vol. 24, pt. 2, 1948, p. 40, pl. 7, figs. 13, 14.

Specimens seem typical as compared with paratypes recorded from O-2 fms., Gulf of Paria, Trinidad, B.W.I.

Many of the specimens have not developed a uniserial stage. I believe these to be young forms and have included them with this species.

Family Silicinidae

Genus Miliammina Heron-Allen and Earland, 1930

Miliammina fusca (H. B. Brady)

Quinqueloculina fusca H. B. Brady, Ann. Mag. Nat. Hist., ser. 4, vol. 6, 1870, p. 47, pl. 11, figs. 2a-c.—Cushman, Bull. 104, U. S. Nat. Mus., pt. 6, 1929, p. 23, pl. 1, figs. 4a-c.—Cushman and Parker, Proc. U. S. Nat. Mus., vol. 80, art. 3, 1931, p. 3, pl. 1, figs. 9a-c.—Cushman, Special Publ. 23, Cushman Lab. Foram. Res., 1948, p. 33, pl. 3, figs. 16, 17.

Miliammina fusca Hada, Zool. Mag., vol. 48, Oct., 1936, p. 852, text fig. 5, Zool. Mag. (Japan), vol. 49, No. 10, 1937, p. 347, text fig. 6.

Specimens have been compared with those recorded from off Cape Stosch Gothoab, Hudson Land, Northeast Greenland, and are typical.

Hada, in his studies on the Foraminifera of brackish water lakes, reports this species as being adapted to brackish waters.

Family Miliolidae

Genus Quinqueloculina d'Orbigny, 1826

Quinqueloculina bidentata d'Orbigny

Plate 1, figure 1

Quinqueloculina bidentata d'Orbigny, in De la Sagra, Hist. Physiq. Pol. Nat. Cuba, 1839, "Foraminifères," p. 197, pl. 12, figs. 18–20—Cushman, U. S. Nat. Mus., Bull. 104, pt. 6, 1929, p. 22, pl. 1, figs. 2a, b.—Said, Special Publ. No. 26, Cushman Lab. Foram. Res. 1949, p. 9, pl. 1, fig. 21.

The specimens have a fairly smooth surface as compared with typical ones.

Quinqueloculina candeiana d'Orbigny

Plate 1, figure 2

Quinqueloculina candeiana d'Orbigny, in de la Sagra, Hist. Physiq. Pol. Nat. Cuba, 1839, "Foraminifères," p. 199, pl. 12, figs. 24–26.—H. B. Brady, Ann. Mag. Nat. Hist., ser. 4, vol. 6, 1870, p. 47, pl. 11, figs. 1a, b.—Cushman, Carnegie Instit. Washington, Publ. No. 311, 1922, p. 65, pl. 13, fig. 1; U. S. Nat. Mus., Bull. 104, pt. 6, 1929, p. 27, pl. 3, figs. 1a-c.—Cushman and Parker, Proc. U. S. Nat. Mus., vol. 80, art. 3, 1931, p. 4, pl. 1, figs. 10a-c.

Specimens are quite typical as compared with those from San Juan Harbor, Puerto Rico, recorded by Cushman.

Quinqueloculina costata d'Orbigny

Plate 1, figure 3

Quinqueloculina costata d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 301, No. 3.—Cushman, Carnegie Instit. Washington, Publ. No. 311, 1922, p. 66, pl. 11, fig. 5—Cushman, U. S. Nat. Mus., Bull. 104, pt. 6, 1929, p. 31, pl. 3, figs. 7a-c.— Kornfeld, Contr. Dept. Geol. Stanford Univ., vol. 1, No. 3, 1931, p. 84, pl. 14, figs. 2a-c.—Parr, Proc. Roy. Soc. Victoria, vol. 56 (n.ser.), pt. 2, 1945, p. 197.

Some of the specimens are quite typical as compared with those recorded by Cushman from shallow water, Moat at Fort Jefferson, Garden Key, Dry Tortugas, Florida. Others are less elongate and more nearly resemble figures of this species from the Gulf of Mexico, recorded by Kornfeld.

Quinqueloculina seminula (Linné)

Plate 1, figure 5

Quinqueloculina seminula Cushman, Bull. 71, U. S. Nat. Mus., pt. 6, 1917, p. 44, pl. 11, fig. 2; U. S. Nat. Mus., Bull. 104, pt. 6, 1929, p. 24, pl. 2, figs. 1, 2.—Kornfeld, Contr. Dept. Geol. Stanford Univ., vol. 1, No. 3, 1931, p. 83, pl. 14, figs. 4a-c.—Cushman, Special Publ. No. 5, Cushman Lab. Foram. Res., 1933, pl. 14, figs. 3, 4.—Phleger and Walton, Amer. Journ. Sci., vol. 248, 1950, p. 288, pl. 1, fig. 20.

Specimens are similar to figures of specimens from Galveston, Texas, recorded by Kornfeld.

This species is widely recorded in the present oceans and is especially common in shallow water along the Atlantic Coast.

Quinqueloculina subpoeyana Cushman

Plate 1, figure 4

Quinqueloculina subpoeyana Cushman, Carnegie Instit. Washington, Publ. No. 311, 1922, p. 66.—Cushman, Bull. 104, U. S. Nat. Mus., pt. 6, 1929, p. 31, pl. 5, figs. 3a-c.—Bermudez, Mem. Soc. Cubana Hist. Nat., vol. 9, 1935, p. 160.

Specimens have been compared with topotypes described by Cushman from the Dry Tortugas, Florida. They differ in having a broader and less elongate test.

Genus Miliolinella Wiesner, 1931

Miliolinella circularis (Bornemann)

Plate 1, figure 6

Triloculina circularis Bornemann, Zeitschr. deutsch. Geol. Ges., vol. 7, 1855, p. 349, pl. 19, fig. 4.
Miliolina circularis H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 169, pl. 4, figs. 3a-c; pl. 5, figs. 13, 14?—Cushman, Bull. 104, U. S. Nat. Mus., pt. 6, 1929, p. 58, pl. 13, figs. 6, 7; pl. 14, figs. 1, 2,—Cushman and Parker, Proc. U. S. Nat. Mus., vol. 80, art. 3, 1931, p. 5, pl. 1, figs. 12a-c.
Miliolinella circularis Oinomikado and Stack, Rept. Comm. Treatise on Marine Ecology and Paleoecology, 1947–48, No. 8, 1948, p. 107 (list).

Specimens here are quite typical of this species which is widely distributed in shallow, tropical waters.

Genus Massilina Schlumberger, 1893

Massilina annectens Schlumberger

Massilina annectens Schlumberger, Mém. Soc. Zool. France, vol. 6, 1893, p. 220, pl. 3, figs. 77–79; text figs. 35, 36, 37—Cushman, Bull. 71, U. S. Nat. Mus., pt. 6, 1917, p. 57, pl. 20, fig. 3; Bull. 104, U. S. Nat. Mus., pt. 6, 1929, p. 39.

I have compared the specimens here with those recorded from Aua Reef, Pago Pago Harbor, Samoa. They differ slightly in having a more compressed test.

Massilina peruviana (d'Orbigny)

Plate 1, figure 7

Quinqueloculina peruviana D'Orbigny, Voy. Amér. Mérid., vol. 5, pt. 5, "Foraminifères," 1839, p. 73, pl. 4, figs. 1–3.
Massilina peruviana Kornfeld, Contr. Dept. Geol. Stanford Univ., vol. 1, no. 3, 1931, p. 85, pl. 14, figs. 1a-c.

Specimens here seem typical and are similar to Kornfeld's figures recorded from the Gulf of Mexico.

Genus Spiroloculina d'Orbigny 1826

Spiroloculina manifesta Cushman and Todd

Plate 1, figure 8

Spiroloculina manifesta Cushman and Todd, Special Publ. No. 11, Cushman Lab. Foram. Res., 1944, p. 62, pl. 8, figs. 26–28.

Specimens have been compared with paratypes recorded by Cushman and Todd from the Philippines, east coast of Mindanao. They differ in having a smaller test and less depressed center.

Genus Triloculina d'Orbigny 1826

Triloculina linneiana d'Orbigny

Plate 1, figure 9

Triloculina linneiana d'Orbigny, in De la Sagra, Hist. Physiq. Pol. Nat. Cuba, 1839. "Foraminifères," p. 172, pl. 9, figs. 11–13.—Cushman, Proc. U. S. Nat. Mus., vol. 59, 1921, p. 70, pl. 17, figs. 3, 4.—Cushman, Bull. 104, U. S. Nat. Mus., pt. 6, 1929, p. 61, pl. 16, figs. 1, 2.

Specimens have been compared with those from Montego Bay, Jamaica, recorded by Cushman, and are typical.

Triloculina oblonga (Montagu)

Plate 1, figure 10

Vermiculum oblongum Montagu, Test. Brit., p. 522, pl. 14, fig. 9—Fleming, Mem. Wernerian Nat. Hist. Soc., vol. 4, 1822, p. 565, pl. 15, fig. 4.

Triloculina oblonga d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 300, No. 16, Modèles N° 95, IV^e^ livraison; in De la Sagra, Hist. Physiq. Pol. Nat. Cuba, 1839, "Foraminifères," p. 175, pl. 10, figs. 3–5.—Parker, Jones and H. B. Brady, Ann. Mag. Nat. Hist., Ser. 3, vol. 16, 1865, p. 34, pl. 1, fig. 9—Cushman, Proc. U. S. Nat. Mus., vol. 59, 1921, p. 69, pl. 17, figs. 5, 6, text fig. 10.—Cushman. Bull. 161, U. S. Nat. Mus., pt. 1, 1932, p. 50, pl. 11, figs. 10a-c.—Oinomikado and Stack, Rept. Comm. Treatise on Marine Ecology and Paleoecology, 1947–48, No. 8, 1948, p. 107 (list).

Specimens are quite typical.

Triloculina trigonula (Lamarck)

Plate 1, figure 11

Miliolites trigonula Lamarck, Ann. du Mus., vol. 5, 1804, p. 351, No. 3.

Triloculina trigonula d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 299, No. 1, pl. 16, figs. 5–9; Modèles, 1826, No. 93.—Cushman, Bull. 71, U. S. Nat. Mus., pt. 6, 1917, p. 65, pl. 25, fig. 3; Proc. U. S. Nat. Mus., Vol. 59, 1921, p. 69; Bull. 161, U. S. Nat. Mus., pt. 1, 1932, p. 56, pl. 13, figs. 1a, b.

Miliolina trigonula Williamson, Rec. Foram. Great Britain, 1858, p. 83, pl. 7, figs. 180–182.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 164, pl. 3, figs. 14–16.

Specimens are typical.

Family Trochamminidae

Genus Trochammina Parker and Jones, 1859

Trochammina inflata (Montagu)

Nautilus inflatus Montagu, Test. Brit., Suppl., 1808, p. 81, pl. 18, fig. 3.

Rotalina inflata Williamson, Rec. Foram. Great Britain, 1858, p. 50, pl. 4, figs. 93, 94.—Parker and Jones, Ann. Mag. Nat. Hist., ser. 3, vol. 4, 1865, p. 174, pl. 8, fig. 8.

Trochammina inflata W. B. Carpenter, Parker and Jones, Introd. Foram., 1862, p. 141, pl. 11, fig. 5.—H. B. Brady, Ann. Mag. Nat. Hist., ser. 4, vol. 6, 1870, p. 50; Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 338, pl. 41, fig. 4a-c.—Balkwill and Wright, Trans. Roy. Irish Acad., vol. 28, Sci., 1885, p. 331.—Brady, Journ. Roy. Micr. Soc., 1887, p. 892.—Hada, Sci. Rept. Tohoku Imp. Univ., ser. 4, Biol., vol. VI, 1931, p. 90, fig. 43 (in text).—Cushman, Special Publ. No. 5, Cushman Lab. Foram. Res., 1933, pl. 18, figs. 3a-c.—Parr, Proc. Roy. Soc. Victoria, vol. 56 (n.ser.), pt. 2, 1945, p. 194, pl. 8, figs. 4a, b.

Specimens here seem typical as compared with those recorded from Coffin's Beach, Annisquam, Mass.

Elsewhere, this species has been noted as being rare except in shallow, brackish water.

Family Polymorphinidae

Genus Guttulina d'Orbigny, 1839

Guttulina spicaeformis (Roemer)

var. australis (d'Orbigny)

Globulina australis d'Orbigny, Voy. Amer. Merid., 1839, vol. 5, pt. 5, Foraminifères, p. 60, pl. 1, figs. 1–4.

Polymorphina australis H. B. Brady, Parker and Jones, Trans. Linn. Soc. London, vol. 27, 1870, p. 239, pl. 41, figs. 27a, b.

Polymorphina regina Cushman, U. S. Geol. Survey Prof. Paper 129, 1922, p. 94, pl. 18, fig. 4; Carnegie Instit. Washington, Publ. No. 311, 1922, p. 33, pl. 4, figs. 5, 6; U. S. Geol. Survey Prof. Paper 133, 1923, p. 33.

Guttulina spicaeformis (Roemer) var. *australis* Cushman and Ozawa, Proc. U. S. Nat. Mus., vol. 77, art. 6, 1930, p. 32, pl. 5, figs. 3a-c.—Bermudez, Mem. Soc. Cubana Hist. Nat., vol. 9, 1935, p. 183.—Hadley, Journ. Elisha Mitchell Sci. Soc., vol. 52, No. 1, 1936, p. 35.

Specimens here are similar to those recorded from the Dry Tortugas, Florida. They differ in having more pronounced costae.

Family Nonionidae

Genus Nonion Montfort, 1808

Nonion pauciloculum Cushman

Plate 1, figure 12

Nonion pauciloculum Cushman, Special Publ. No. 12, Cushman Lab. Foram. Res., 1944, p. 24, pl. 3, fig. 25.

Specimens have been compared with paratypes recorded by Cushman from Buzzards Bay and are typical.

Genus Elphidium Montfort, 1808

Elphidium advenum (Cushman)

Elphidium advenum Cushman, Bull. 104, U. S. Nat. Mus., pt. 7, 1930, p. 25, pl. 10, figs. 1, 2; Bull. 161, U. S. Nat. Mus., pt. 2, 1933, p. 50, pl. 12, figs. 1–3; U. S. Geol. Survey Prof. Paper 191, 1939, p. 60, pl. 16, figs. 31–35.

This species, originally described from the Dry Tortugas of Florida, is widely distributed in warm waters of the western Atlantic and the Pacific.

Elphidium articulatum (d'Orbigny)

Plate 1, figure 13

Polystomella articulata d'Orbigny, Voy. Amér. Mérid., vol. 5, pt. 5, Foraminifères, 1839, p. 30, pl. 3, figs. 9, 10.

Elphidium articulatum Cushman, Bull. 104, U. S. Nat. Mus., pt. 7, 1930, p. 26, pl. 10, figs. 6–8; U. S. Geol. Survey Prof. Paper 191, 1939, p. 53, pl. 14, figs. 17–19.—Cushman and McCulloch, Allan Hancock Pacific Exped., vol. 6, no. 3, 1940, p. 171, pl. 19, fig. 7.

This is a widely distributed species, having been recorded mostly from off the coast of South America and also Cuba.

Elphidium gunteri Cole var. galvestonensis Kornfeld

Plate 1, figure 14

Elphidium gunteri Cole var. *galvestonensis* Kornfeld, Contr. Dept. Geol. Stanford Univ., vol. 1, No. 3, 1931, p. 87, pl. 15, figs. 1–3.—Cushman, U. S. Geol. Survey Prof. Paper 191, 1939, p. 60, pl. 16, fig. 25.

Specimens are referable to this species, which is prevalent here in all facies.

Kornfeld reported it as "a common constituent of foraminiferal faunas in the shallow subtropical waters of the Gulf of Mexico from the Rio Grande to the Mississippi River."

Elphidium incertum (Williamson)

Polystomella umbilicatula var. *incerta* Williamson. Recent Foraminifera of Great Britain, p. 44, pl. 3, figs. 82, 82a, 1858.

Polystomella striato-punctata var. *incerta* Kiaer, Rep't Norwegian Fish. Mar. Invest., vol. 1, no. 7, p. 51, 1900.—Cushman, Rept. Canadian Arctic Exped., pt. M, p. 10, 1913.

Elphidium incertum Cushman, U. S. Nat. Mus. Bull. 104, pt. 7, p. 18, pl. 7, figs. 4–9, 1930; Florida Geol. Survey Bull. 4, p. 39, pl. 7, figs. 2a, b, 1930; U. S. Geol. Survey Prof. Paper 191, 1939, p. 57, pl. 15, figs. 21–24.—Parker, Bull. Mus. Comp. Zool., vol. 100, 1948, p. 238 (list), pl. 5, fig. 7.

I have compared specimens here with those collected by Cushman from Casco Bay, Maine, and they are referable to this species.

Elsewhere it is known to be common in cold waters.

Elphidium morenoi Bermudez

Plate 1, figure 15

Elphidium morenoi Bermudez, Soc. Cubana Hist. Nat. Mem., vol. 9, p. 188, pl. 13, figs. 7–9, 1935.—Cushman, U. S. Geol. Survey Prof. Paper 191, 1939, p. 59, pl. 16, fig. 29.

The types of this species are from the north shore of Cuba. Cushman found it very common at Key West, Florida, and considers it having a fairly wide range in the general West Indian region.

Elphidium poeyanum (d'Orbigny)

Plate 1, figure 16

Polystomella poeyana d'Orbigny, in De la Sagra, Hist. Physiq. Pol. Nat. Cuba, "Foraminifères," p. 55, pl. 6, figs. 25, 26, 1839.

Elphidium poeyanum Cushman, U. S. Nat. Mus. Bull. 104, pt. 7, p. 25, pl. 10, figs. 4, 5, 1930; Florida Geol. Survey Bull. 4, p. 39, pl. 7, figs. 3, 4, 1930; U. S. Geol. Survey Prof. Paper 191, 1939, p. 54, pl. 14, figs. 25, 26.

Specimens have been compared with those recorded from the Dry Tortugas, Florida, and are referable to this species. This is a common species in the West Indian region.

Elphidium translucens Natland

Plate 1, figure 17

Elphidium translucens Natland, Bull. Scripps. Instit. Ocean., Tech. ser., vol. 4, No. 5, 1938, p. 144, pl. 5, figs. 3, 4.—Cushman, U. S. Geol. Survey Prof. Paper 191, 1939, p. 65, pl. 20, figs. 7a, b.—Cushman and McCulloch, Allan Hancock Pacific Exped., vol. 6, no. 3, 1940, p. 172, pl. 19, fig. 9.

Specimens seem typical as compared with paratypes recorded by Natland from off California. This is essentially a shallow-water species.

Family Buliminidae

Genus Buliminella Cushman, 1911

Buliminella elegantissima (d'Orbigny)

Plate 1, figure 18

Bulimina elegantissima d'Orbigny, Voy. Amer. Merid., vol. 5, pt. 5, "Foraminifères," 1839, p. 51, pl. 7, figs. 13, 14.—Williamson, Recent Foram. Gt. Britain, 1858, p. 64, pl. 5, figs. 134, 135.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 402, pl. 50, figs. 20–22.—Heron-Allen and Earland, *Discovery* Repts., vol. 4, 1932, p. 351, pl. 8, figs. 35–37.

Buliminella elegantissima Cushman, Proc. U. S. Nat. Mus., vol. 56, 1919, p. 606; Cushman, Special Publ. No. 4, Cushman Lab. Foram. Res., 1933, pl. 22, fig. 3.—Cushman and Parker, U. S. Geol. Survey Prof. Paper 210-D, 1947, p. 67, pl. 17, figs. 10–12.

Specimens here are quite typical as compared with those from off Chile and Peru. This is a widely distributed species in the present oceans.

Genus Bolivina d'Orbigny, 1839

Bolivina striatula Cushman

Plate 1, figure 19

Bolivina striatula Cushman, Carnegie Instit. Washington. Publ. No. 311, 1922, p. 27, pl. 3, fig. 10; Bull. 104, U. S. Nat. Mus., pt. 3, 1922, p. 43; Special Publ. No. 9, Cushman Lab. Foram. Res. 1937, p. 154, pl. 18, figs. 30, 31.—Asano, Jour. Geol. Soc. Japan, vol. 45, No. 538, 1938, p. 604, pl. 16 (5), fig. 18—Cushman, U. S. Nat. Mus., Bull. 161, pt. 3, 1942, p. 30, pl. 9, fig. 1.

Specimens have been compared with paratypes from the Dry Tortugas, Florida, and are typical.

This species is common in the West Indian region.

Explanation of Plate 1

Figure

1. *Quinqueloculina bidentata* d'Orbigny. x 32. Loc. No. 52.
2. *Quinqueloculina candeiana* d'Orbigny. x 42. Loc. No. 53.
3. *Quinqueloculina costata* d'Orbigny. x 58. Loc. No. 53.
4. *Quinqueloculina subpoeyana* Cushman. x 58. Loc. No. 52.
5. *Quinqueloculina seminula* (Linné). x 58. Loc. No. 57.
6. *Miliolinella circularis* (Bornemann). x 67. Loc. No. 53.
7. *Massilina peruviana* (d'Orbigny). x 33. Loc. No. 69.
8. *Spiroloculina manifesta* Cushman and Todd. x 33. Loc. No. 46.
9. *Triloculina linneiana* d'Orbigny. x 33. Loc. No. 50.
10. *Triloculina oblonga* (Montagu). x 100. Loc. No. 50.
11. *Triloculina trigonula* (Lamarck). x 58. Loc. No. 69.
12. *Nonion pauciloculum* Cushman. x 83. Loc. No. 53.
13. *Elphidium articulatum* (d'Orbigny). x 83. Loc. No. 57.
14. *Elphidium gunteri* Cole var. *galvestonensis* Kornfeld. x 42. Loc. No. 57.
15. *Elphidium morenoi* Bermudez. x 42. Loc. No. 53.
16. *Elphidium poeyanum* (d'Orbigny). x 83. Loc. No. 53.
17. *Elphidium translucens* Natland. x 42. Loc. No. 69.
18. *Buliminella elegantissima* (d'Orbigny). x 150. Loc. No. 13.
19. *Bolivina striatula* Cushman. x 100. Loc. No. 13.
20. *Rotalia beccarii* (Linné). x 42. Loc. No. 53.
21, 22. *Rotalia beccarii* (Linné) var. *tepida* Cushman. x 100. 21, Dorsal view; ventral view, Loc. No. 31.

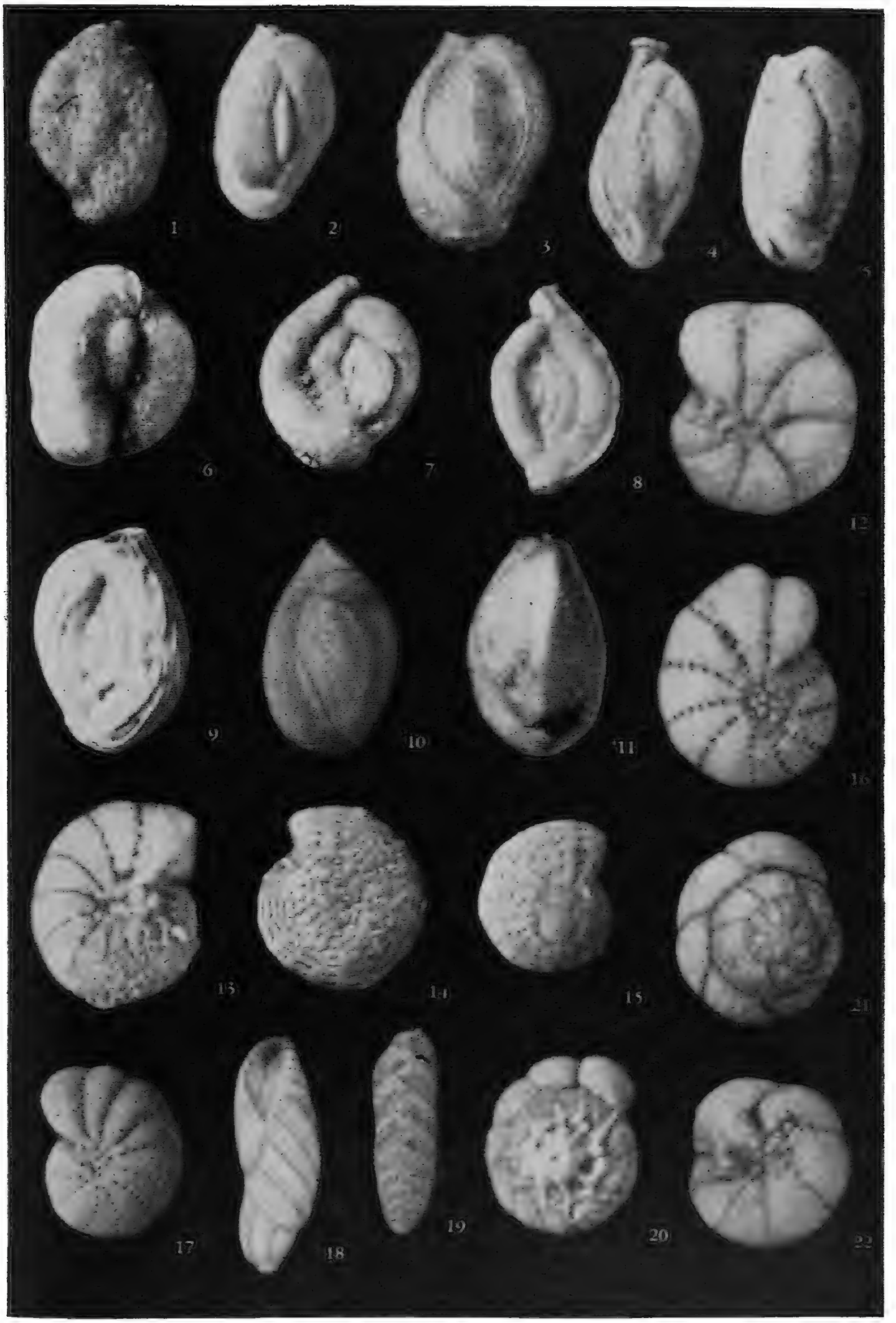

PLATE I

Family Rotaliidae

Genus Rotalia Lamarck, 1804

Rotalia beccarii (Linné)

Plate 1, figure 20

Nautilus beccarii Linné, Syst. Nat., Ed. 12, 1776, p. 1162.

Rotalia beccarii d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 275, No. 42; Modèles, No. 74.—Williamson, Recent Foram. Gt. Britain, 1858, p. 48, pl. 4, figs. 90–92.—Cushman, Proc. Boston Soc. Nat. Hist., vol. 34, No. 2, 1908, U. S. Nat. Mus., Bull. 71, pt. 5, 1915, p. 67, pl. 30; U. S. Nat Mus., Bull. 104, pt. 8, 1931, p. 58, pl. 12, figs. 1–7; pl. 13, figs. 1, 2.—Hada, Zool. Mag., vol. 48, Oct., 1936, p. 855, text fig. 8.—Morishima, Rept. Comm. Treatise on Marine Ecology and Paleoecology, 1946–47, No. 7, 1948, p. 91.

Here, the specimens are smaller than typical.

Rotalia beccarii (Linné)

var. tepida Cushman

Plate 1, figures 21, 22

Rotalia beccarii (Linnaeus) var. *tepida* Cushman, Publ. 344, Carnegie Instit. Washington, 1926, p. 79, pl. 1.—Kornfeld, Contr. Dept. Geol. Stanford Univ., vol. 1, No. 3, 1931, p. 91, pl. 13, figs.3a–c.—Cushman, Bull. 104, U. S. Nat. Mus., pt. 8, 1931, p. 61, pl. 13, figs. 3a–c.

Specimens are quite typical as compared with those from San Juan Harbor, Puerto Rico.

Cushman recorded this variety as common in warm, protected waters in the West Indian region.

Family Anomalinidae

Genus Cibicides Montfort, 1808

Cibicides concentricus (Cushman)

Truncatulina concentrica Cushman, Bull. 676, U. S. Geol. Surv., 1918, p. 64, pl. 21, fig. 3; Bull. 4, Fla. Geol. Survey, 1930, p. 61, pl. 12, figs. 4a–c.

Cibicides concentrica Cushman, Bull. 104, U. S. Nat. Mus., pt. 8, 1931, p. 120, pl. 21, figs. 4, 5; pl. 22, figs. 1, 2.—Parker, Bull. Mus. Comp. Zool., vol. 100, 1948, p. 237 (list), pl. 1, fig. 16.

Specimens are typical of this warm water species which is common off Florida and in the West Indian region.

Some Principles of Marine Fishery Biology

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ABSTRACT

From consideration of the nature of productive relationships within marine ecosystems and from critical comparison of the studies of Pacific halibut and North Sea demersal fisheries, it appears that deductive methods may not, in the present state of marine science, permit reliable prediction of the effects of fishing.

Deliberate use of the inductive method, through design of sea-fishery regulations in form equivalent to controlled experiment, may thus often be necessary for achievement of biologically effectual exploitation.

The net value to society of the given purpose which would be effectually served by a given mode of exploitation is difficult to assay. However, the attendant increase in knowledge of interactions between man and environment may be of prime importance.

Some Principles of Marine Fishery Biology

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I. The Relations of Biology to Marine Fishery Management:

1. Viewpoint of management:

Marine fishery biology is an applied science concerned with improvement of exploitation of the living resources of the sea. The discovery of exploitable stocks and the improvement of techniques of utilization through application of biological knowledge are within its sphere; but its present major function is to discover the causes of change in availability and quality of stocks in use, to predict the future course of such changes, and to describe the biological requirements for control or modification of these changes.

Marine fishery biology thus at present serves chiefly as one of the bases for fishery management. The latter is, as Sette observes (1943, p. 4), essentially a branch of political economy. Considerable confusion among fishery biologists has been caused by failure of some to realize clearly that the advantage sought by their science is that of man, not fish; while equal confusion seems to have been caused among political economists by failure to realize that social advantages of management depend at bottom upon biological reactions and environmental changes which are as yet not fully predictable.

Without attempting to consider in detail the question of the importance of social advantages obtainable from marine fishery management, it is desirable to touch upon the matter here. Management consists in deliberate effort to improve upon the results which would be obtained from fishing through the uncontrolled interplay of social and economic forces. Two fundamental objections might be raised against it: first, that deliberate control must to some extent at least reduce the flexibility of social response, through hindrance of individual initiative and enterprise; and second, that the maximum tangible gains from marine fishery management are relatively so small as perhaps not to be worth the requisite expenditure of public effort.

The second objection may be enlarged upon as follows: The tangible gain to be expected from marine fishery management is the prevention of wastage of fishing effort. It is true that on the fringes of the sea, great changes may be produced in intracoastal and anadromous fishery stocks through human activities other than fishing. Wastage of potential catch is here a prime concern; as also in the case of stocks where individuals are sufficiently valuable or accessible, fecundity and rate of maturation are sufficiently low, and rate of irreducible natural mortality is sufficiently high to permit the stock to be fished for profit down to a level where extinction will ensue. But such marginal wastages of catch may also be considered

in terms of waste of effort, since their effect is to throw more effort into fisheries which would otherwise not be profitable. For most of the great sea-fisheries, human influence is limited, and waste of effort is the direct and only concern. There is, for any particular living stock or size-group thereof, a level of reduction in abundance caused by fishing below which *(ceteris paribus)* the previously increasing rate at which the stock replaces withdrawals begins to decline. Consequently, there are biologically-conditioned inflection points in the curve of diminishing returns from increased fishing effort; and effort may be saved if the sustained intensity of fishing is not permitted to drive the stock below levels at which the inflection-points develop. [It should be noted that, above the inflection-points, increase in abundance can be obtained through restriction of fishing only by wastage of potential catch; that is, by sacrifice of a part of the harvest with which the stock is capable of maintaining an equilibrium. Net social gains from prescriptive restriction at levels of abundance higher than the critical ones are thus not easily defined].

But fishing-effort saved can be regarded as a net gain to society only to the extent that the costs of management would not have caused still more improvement in social efficiency if otherwise applied. For example, it might be fair to say that waste of effort in supplying the demand for cod, resulting from North Sea overfishing, can occur only because the markets supplied with North Sea cod do not sufficiently accept the (presumably) nutritionally equivalent and cheaper herring. Beyond this relatively minor irrationality of food-preference is a similar but much greater one which results in the consumption of more animal products (especially the expensive terrestrial ones) than is required for maximum physiological well-being. It is thus a legitimate question whether the costs of fishery management might not produce greater savings if applied instead to the greater problem.

It is certainly possible to argue that overfishing is no real problem as regards the irreducible costs of human nourishment. Before North Sea herring and, after them, Humboldt Current stocks are overfished for direct human consumption, it would become cheaper to supply and more profitable to fish herbivores of the Antarctic upwelling (assuming that appropriate technological developments are feasible, and if tastes in foods and in forms of social organization would permit). The harvest of these last required to reduce their abundance to the level for the biological inflection points is (for reasons which will appear in the discussion of marine productivity below) probably staggering as compared with that for the shallow continental sea-areas.[1]

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[1]The above fundamental objections appear to be the principal basis of the pessimistic view of the advantages of prescriptive restriction reached by Taylor (1951). However, his presentation is rather incoherent; he does not deal with the problem of what constitutes potential availability of substitutes, nor make consistent distinction between advantage to producers and those to society at large; and his argument is vitiated by failure to consider the biologically conditioned inflection-points in the curve of diminishing returns from increased fishing (and by misapprehensions concerning the dynamics of productivity).

For example (*ibid.*, pp. 289–90, 402–403, 422), he seems to conclude that prescriptive restriction of the Great Lakes fishery is not needed, since "scarcity has produced a disproportionate rise in prices which was decidedly advantageous to the fishermen as a group" while at the same time substitute fisheries were stimulated elsewhere to satisfy the market. But if the Great Lakes stocks have been fished below their limit for maximum equilibrium yield (a controversial question), costs of production may have risen as disproportionately as did prices. The supposed advantage to fishermen rests on the observation that despite a reduced total catch "percentage improvement in income in dollars of constant purchasing power per fisherman exceeds that of

Against these above-discussed fundamental doubts concerning advantages of marine fishery management, it has to be considered that knowledge is likely to be advanced more rapidly through efforts at management than without them. To balance the reduction in flexibility of response which might be caused by prescriptive regulation, an increase in flexibility ought to be permitted by better knowledge. To balance the relative insignificance of tangible gains from restrictions, there are not many other directions in which experience in deliberate effort to improve social efficiency can so readily be gained; and such experience ought to increase the likelihood of success in dealing with greater problems. These considerations are of the greatest importance. Therefore, whenever managment may legitimately be expected to increase the rate of improvement of knowledge, and also to produce tangible gains which in the long run would be greater than the equally tangible costs to society in general, it seems worth undertaking.

Reliable prediction of tangible net gains from proposed management of a given fishery is, however, difficult. The relations of catch to price are even more complex than those of catch to cost, and the relevant data are perhaps even more difficult to gather, interpret and use for extrapolation. At the same time the socioeconomic sciences do not seem to have developed far enough as yet to permit assured identification of causality among observed correlations, even under circumstances which would provide fairly firm inductive ground for biology. And in addition, the inaccuracy and the inadequate range which are at present inherent in predictions concerning socioeconomic effects of change in fishery stocks are geometrically increased by error in their premises; which premises are the biological predictions concerning effects of a given mode of exploitation. Consequently, although reliable biological predictions are by no means the only requirement for successful management, without them the unreliability of socioeconomic predictions is multiplied.

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any other region"; but this is the *gross* income (total catch times average price, divided by estimated number of fishermen), and if costs of production were deducted, the *net* income might be found to have declined with scarcity despite the increase in the gross (a possibility consistent with the fact that a sharp decline in the number of Great Lakes fishermen is reported). Further, there seems no reason why the same rise in price could not have been obtained by prescriptive restriction of fishing while the stocks were more abundant, which might therefore have been more favorable to fishermen's profits than *laissez faire*, whether or not Great Lakes fishing has been so intense as to reduce the stocks below their level for maximum equilibrium yield.

Turning now to the belief that the consumer of Great Lakes fish was not injured by scarcity because substitutes were supplied, it will be obvious that if prices of Great Lakes fish rose disproportionately, substitution was inadequate to satisfy demand. If it has been the case that Great Lakes fishing effort was sustained after the stocks were driven below the level for maximum equilibrium yield, substitution must have been insufficient to prevent waste of effort for which someone would have to pay: producer, consumer or both. In other words, price of fish accepted by the market would in consequence of overfishing have become unnecessarily high, or profits from Great Lakes fishing unnecessarily low, or both. If the same price increase had been caused by restriction of the Great Lakes catch to less than the maximum with which the stocks could maintain equilibrium, while they were above the critical point, unnecessarily high prices to consumers would at least have been counterbalanced by greater net profits to Great Lakes producers or distributors.

. It should be noted that the maxim with which the Great Lakes situation is dismissed (*ibid.*, pp. 403, 422) "*it is impossible to exhaust a fishery for profit because the profit disappears before the fish does,*" is speciously employed. A fishery may continue profitable to fishermen even though exhausted to such an extent that effort is being wasted with the sole effect of reducing the catch. Such waste may be contrary to the public interest in the same way as when lumbering is so conducted as to slow the rate of reforestation unnecessarily. The quoted maxim is used as if it meant that self-regulating factors ensure use of fish-stocks in the manner most advantageous to society; whereas its only real meaning is that changes caused by most commercial fishing are likely to be reversible under appropriate conditions.

For example, the degree to which management of the Pacific halibut fishery could be termed advantageous to society has really never been fully examined. Even if there were no serious difference of opinion concerning the biological effects of the regulations, the socioeconomic changes accompanying management of this fishery do not seem to have been objectively observed and evaluated. Yet, the ratio of the quotas permitted to be taken from Area 2 and Area 3 must have affected the welfare of western Canadian and Alaskan landing ports relative to that of Seattle; the shortness of the fishing season, which requires frozen storage of much of the catch and part-year idleness of some of the boats and men, must have affected the charges on the consumer; the restrictions on otter-trawling of halibut must have hampered the utilization of the rock-cod resource; etc. Although accumulation of experience, even without experimental controls, may in the end reduce doubts concerning causation of the biological changes coincident with those in halibut fishing, it does not seem likely to cause equal improvement in the understanding of socioeconomic consequences. At the same time, until it is certain that the halibut stock cannot by reduction of abundance be made to sustain a greater catch than that now permitted, evaluation of gains from management cannot be begun.

2. Viewpoint of biology:

From its manner of use, the phrase "rational exploitation" is evidently intended by fishery biologists to mean, what should be taken from a fishery stock per unit of time in order to obtain the greatest returns, in given value-terms, to a given part of human society over a given period. But since any particular given premises would represent no more than selection among numerous possibilities, any policy of fishery management based on them might in one way or another be defended as rational or criticized as irrational, according to opinion as to what actual or potential fisheries of a region, value-terms, social groups, or length of time ought to be included. In practice, exhaustive consideration is not given by biologists to all the premises underlying their proposals for "rational exploitation." The feature common to all such proposals is, that they are intended to produce some particular biological result. For example, the term has been used in reference to the "optimal catch."

What is rather deceptively termed the "optimal catch" by fishery biologists is a clearly definable and specialized concept, with extensive implications, which is firmly based upon the theory of population growth. It means, the highest yield per unit time with which the particular stock considered could maintain equilibrium under the prevailing environmental conditions. This concept of maximum equilibrium yield[2] must play an important part in value judgments on whatever premises, since it defines an inflection point in the curve of diminishing returns of fish from increasing expenditure of fishing effort.

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[2]The term *equilibrium yield* will here be used in place of the synonymous and more usual "sustainable catch", because the latter becomes liable to misunderstanding in cases where the potential equilibrium of catch with abundance is being displaced by natural changes (unless the phrase is expanded to the form "catch sustainable under prevailing environmental conditions"). In other words, a given equilibrium yield is not the fixed characteristic of a given stock-level but would vary as systematically as do environmental affects (such as, say currents, which drift eggs and larvae from spawning areas to optimal nursery grounds). At the same time, social changes may prevent maintenance of a catch equal to the equilibrium yield. Therefore a given biologically "sustainable" catch often does not in reality remain sustainable. This causes verbal confusion which is avoided by the substitute term, equilibrium yield.

However, this inflection point is not the only one with a biological basis. Another, occurring at stock levels above that for maximum equilibrium yield, is a consequence of difference in slope of the curve of change in equilibrium catch from that of the curve of change in the corresponding abundance of the stock. The sacrifice of potential catch required to raise abundance above the level for maximum equilibrium yield thus has a point of maximum return. For example, reduction of catch to some 7 per cent below the equilibrium limit which has been calculated for marketable North Sea trawl fish by Baerends (1947, Fig. 1, using the ingenious method of Graham, 1935) would evidently correspond to a 25 per cent increase in the equilibrium stock. Greater or lesser hypothetical reduction in the catch would result in proportionately less improvement in hypothetical catch per unit effort.

Suppose that both price per ton of fish and costs of a unit of fishing-effort were fixed at a level such that the value of the maximum equilibrium yield would not be a great deal more than the costs of obtaining it. The hypothetical equilibrium catch of 93 per cent of the maximum one calculated by Baerends would then be that of maximum net value of the total catch. In reality, of course, changes in tonnage of fish caught, in character of the stock, and in effort expended (all having interdependence) would entail change both in cost of a unit of effort and in the relation of quality and magnitude of catch to demand, hence in price of fish. Therefore, even assuming all independent factors unchanged, the theoretical point of maximum product of equilibrium yield times corresponding catch per unit effort is by no means necessarily that of maximum sustainable net monetary return from the fishery (let alone necessarily optimal in a broad sense). Nevertheless, value judgments are incomplete without consideration of this second biologically defined inflection point (*cf.* Graham, 1935, pp. 265, 274); which may be termed that of *maximum net product;* and which may be defined algebraically as that at which $C_e^2/f_e = max.$, when C_e is equilibrium yield, and f_e is the fishing-effort required to obtain this catch when the stock has reached equilibrium with it.

In addition to the direct effects of a particular fishery on its particular stock, repercussions on the environment must also be allowed weight in appraising the results of exploitation. The given fishery has in the first place to be considered not alone but in its relation to others based on stocks comprised in the same ecosystem. For example, certain valuable fish *(Sciaenops* and *Cynoscion)* of the southern United States annually consume several times their weight of shrimp *(Penaeus),* which latter support the most valuable fishery of the region. A third of a century ago, the shrimp catch was about double that of these fish, but sold at only a third of the price per pound, and it might have seemed clear that the fish-stocks ought not to be driven below their level for maximum equilibrium yield. The shrimp catch has subsequently quadrupled, while the commercial catch of the fish remains much the same; and the relative price of shrimp has risen to two-thirds or more. The present yearly consumption of shrimp by these fish is probably on the order of the present annual shrimp catch by man, which latter may be considerably more than the average standing crop of shrimp. It will be seen that the limits and costs of production of the shrimp would have to be considered in relation to those of the fish; and that a catch of the fish greater than would permit equilibrium might seem advantageous from some points of view.

As a more far-fetched example of the necessity of considering indirect fishery-dependent changes, it may be noted that although important North Sea demersal stocks have probably been driven by fishing below the level for maximum equilibrium yield, the potential North Sea balance of yield and cost of potential food might not necessarily have been much changed (thus, Graham, 1949, remarks the possibility that demersal "trash" has been favored, and herring might conceivably have benefited from reduced predation by cod). A rational trend in human consumption of fish might be toward processed forms, like Indonesian trassi, which reduce dependence on raw kind and size. Thus, if increasing scarcity of choice North Sea demersal fish were to be more or less quantitatively compensated by increasing abundance of less desired ones, and if this would favor the development of preference for processed substitutes, the ultimate result might conceivably be more advantageous to European society than that from restriction of the fishery to an equilibrium catch of demersal species and sizes now valued.

In addition, fishery-dependent effects on environment may have more subtle and important consequences than the above. These arise from circular readjustments in composition of the biomass which may in some cases include significant modification of basic photosynthetic production, as discussed in the next chapter.

Beyond any consequences of fishing, the direct and indirect effects of independent environmental change must also play a part in value judgments. There are numerous indisputable instances in which fishery-independent affects have overwhelmingly outweighed fishing. There are probably also cases in which it may be doubted if overfishing during a period of abundance would have much influence upon the time or extent of the next expansion of the stock following an intervening period of unfavorable natural conditions (*cf.* Burkenroad, 1946*a*, pp. 52–7). In appropriate circumstances, a catch greater than could be indefinitely sustained by the stock might thus sálvage what would otherwise be lost (as has been suggested by Gunter, 1951, for Texas bay fishes, which are periodically killed by catastrophic cold). Further, the misidentification of changes in abundance caused by fishery-independent affects may result in erroneous estimates of equilibrium yield.

Thus, use of the term "optimum" to designate an estimate of the maximum equilibrium yield may be injudicious, especially since fishery administrators and legislators, and even biologists themselves, seem sometimes to be confused by the broader connotations of the word. "Rational," as employed by fishery biologists, likewise seems to have undesirable implications; since the reasonableness of an exploitation policy depends not only on the relation between its biological effects and the end desired, but on the rationality of the end (which, being a social matter, is difficult to judge, especially in advance). The fishery biologist, as such, is trained for objective consideration of the methods and effects of human predation on the aquatic biota, but not of the more intricate counter-influences upon society. To learn and advise what kind, size and number of fish would be taken over what period by how much of what kind of effort is a function not to be confused with that of deciding what effort would be most advantageous to society (*cf.* Sette, 1943, p. 4). The special function of the fishery biologist with respect to management is to determine the requirements for *biologically effectual exploitation* (a phrase intended to mean, that form of exploitation which will effectually produce a given

biological result; and which is therefore noncommittal as to the value of the given purpose to be answered by the biological result).

Attention may now be turned to the chief purpose of the present essay, which is to examine the degrees and causes of reliability of conclusions concerning biologically effectual exploitation of marine fisheries. It will be shown that, at the present level of development of marine science, the biological effects of fishing are probably not predictable with requisite range and accuracy by the deductive methods upon which (except by accident, as in the North Sea) reliance has been chiefly placed.

II. The Effects of Environmental Change Dependent on Fishing.

1. Ultimate limits of potential harvest.

To introduce the problem of marine productivity, it is useful to compare a shallow sea with a fish-pond. Oriental salt-water ponds utilizing food-chains of minimal length may yield as much as 5,000–7,000 lb. fish/acre/year (*cf.* Harvey, 1950, p. 132), which is more than 300 times the comparable yield from the North Sea. However, the pond harvest would annually remove some 30–40 pounds of phosphorus per acre. The original upper six inches of pond-bottom might contain several hundred pounds of phosphorus; but even if this store in the bottom were subject to deduction after the first year or so (rather than, as is likely despite periodic draining and ploughing, to accretion), our present concern is with the sustainable yield of phosphorus, which could not exceed the income. Assuming a two meter depth of water in the pond, 35 lb./acre of annual phosphorus harvest would amount to some 2 $g/m^3/yr$. Suppose that the natural waters available were to average, say, 20 mg P/m^3. Removal of all the phosphorus from 100 fillings of the pond would then be required to balance the year's harvest. Even if it were possible to create a condition in which the producers were all attached and the pond could be completely emptied on every suitable tide without killing the biota, photosynthesis would be slowed as the depletion of the nutrient in a filling of water proceeded, impeding the extraction of phosphorus from intake-water at the rate required to balance the given harvest. A sustained annual yield of 35 lb./P per acre of pond would thus in practice evidently require a supplementary supply of the nutrient element (as from human wastes).

If, now, the fish-pond is imagined expanded to North Sea dimensions (575,000 km^2 $\times$ 96m), the anabolic function would have to be conducted chiefly by phytoplankton instead of attached vegetation. To the extent that the producers would now freely drift out of the region considered with the water from which they have removed phosphate, there would be no differential in phosphorus content between in- and out-flowing water, hence the system would have no sustainable yield. However, in addition to simple sinking and turbulence which carry the plankton within range of the bottom fauna, a unit mass of planktonic herbivores is believed to take a quantity of plants per unit time which increases with the standing crop of plants, even when this rate rises above that of assimilation. At densities of phytoplankton too high for the graze to be fully used by the standing crop of planktonic herbivores, an excess is therefore discharged undigested but with its sinking rate enhanced, and so remains in the region. At the same time, planktonic herbivores not only in part metamorphose to sessile forms, but are in part consumed by a nekton which can

maintain itself within the limits of the system against the outflow; and this process of retention is further assisted by predation of nekton by some of the demersal fishes. A differential between inflow and outflow can thereby be established, which can serve to balance phosphorus losses incurred by the irretrievable burial of nutrient in the bottom, and by terrestrial harvests. Thus, while the long food-chains of the sea dissipate energy, they may in appropriate circumstances increase the local availability of phosphorus to a more-than-compensatory degree.

With a depth 50 times that in the model fish-pond, the model North Sea could evidently obtain phosphorus equivalent to the given fish-pond harvest by complete depletion of two annual fillings of water containing 20 mg P/m^3. However, the available North Sea exchange sources evidently average less rich, the rate of water-exchange may not be so rapid, the outgoing water is evidently far from completely depleted, and the unrecoverable losses to the bottom must be considerable.[3] If usable terrestrial contributions from North Europe were less than the Mississippi River discharges to the Gulf of Mexico (therefore probably less than 10,000 tons of phosphorus per annum; *cf.* Riley, 1938, p. 168), and if losses to the bottom were, say, 50,000 tons P/yr., maintenance of phosphorus balance even under natural conditions would evidently require one annual exchange of the North Sea water mass with the ocean at an average differential of nearly 1 mg P/m^3.

The North Sea fish catch removes some 10,000 tons P/yr. If this were a cumulative loss, it would probably amount in a century to nearly as much as the equilibrium store of the element on hand in the North Sea.[4] It does not, however, seem

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[3]Suppose, for purposes of illustration, that the upper centimeter of North Sea bottom has a dry weight of 0.5 g/cc, with an average of 4 per cent nonliving organic matter which contains phosphorus to 1 per cent of its own weight; that the rate of deposition is 1 mm per year; and that after 20 years the original upper centimeter has lost two-thirds of its organic phosphorus by regeneration, the remainder being unrecoverable (*cf.* Sverdrup, *et al.*, 1946, pp. 230–1, 1015–6). On this basis, there might be some 1,200,000 tons of nonliving organic phosphorus in the upper centimeter of the bottom (on the order of 10 times as much as in the average benthonic standing crop, to judge from estimates of the latter for the English Channel by Harvey, 1950, p. 129). This accumulation would be in equilibrium with some 150,000 tons P regenerated yearly, and 50,000 tons P permanently buried.

If the oceans as a whole are not losing phosphorus, gains from the land must balance losses to the bottom; hence the above hypothetical North Sea situation would not be typical. An oceanic balance would of course have the whole world and geological periods of time for its maintenance; on the other hand, the present is probably a period of relatively great erosion and the Mississippi River a relatively great carrier of phosphorus. On this basis, the above hypothetical rate of loss to the North Sea bottom sounds rather high, although this argument against it is not telling. A study of the problem would be of importance.

[4]Channel winter phosphate maxima (Cooper, 1948, p. 335; Harvey, 1950, p. 135) would be equivalent to a North Sea range between 1.4 g P per m^2 of area (equalling the average of the phosphate-poor period in the Channel, 1931–39 and 1949) and 2.1 g P/m^2 (equalling the phosphate-rich period in the Channel, 1925–29); or 800,000–1,200,000 tons total. To this should probably be added some 10 per cent for dissolved organic phosphorus. The winter maximum of total water-borne phosphorus in the Channel is evidently only some 25 per cent above the summer minimum, but unless this difference results wholly from exchange with seasonally depleted ocean water, it might represent a considerable temporary accumulation in the bottom and the non-planktonic biomass; so that the whole of the average biomass could not be regarded as containing phosphorus additional to the winter phosphate maximum. The average biomass, as derived from the estimate in terms of dry organic matter per m^2 in the Channel by Harvey (1950, p. 129), would be on the order of 50 times the annual North Sea fish catch, but its phosphorus content per pound would probably average less than half that of fish. This would amount to some 350 mg P/m^2 or 200,000 tons (of which the amount allocated by Harvey to the average standing crop of plankton would equal some 65 mg P/m^2, or 40,000 tons). To the corrected sum should be added the amount of phosphorus yearly regenerated from nonliving organic matter in the bottom. The average total equilibrium store of potentially usable phosphorus on hand in the North Sea might thus be some one and a third million tons.

likely that this drain by fishing would have a cumulative effect on the phosphate content of the water (as evidently thought by Baerends, 1947, p. 25), since it would amount to less than 0.2 mg P/m^3/yr., little more than a hundredth of the presumptive average winter phosphate maximum, some thirtieth of the average difference between rich and poor years of winter maximum off Plymouth, and a quarter of the above-assumed natural differential between in- and out-flowing North Sea water. The direct effect of present fishing could thus be compensated by an undetectable reduction in the average content of total phosphorus in the outflowing water, probably much smaller than what may occur during adjustments of the system's balance to natural fluctuations in phosphorus content of inflowing water.

At the same time, however, it will be seen that the ultimate limit for sustainable North Sea yield of organic matter in any form might not exceed the present harvest by tens of times (if so much). A tenfold increase in the harvest would require for balance a complete annual exchange of water at a phosphorus differential averaging some 2 mg/m^3/yr. more than the excess of irretrievable losses into the bottom over usable income from the land. This might be incompatible with maintenance of the living balance on which the availability of the phosphorus income depends, since this income cannot be regarded as a fixed quantity independent of the biota. The gross inflow from rivers and ocean is, indeed, independent; but the amount which can be harvested from the system without unbalancing the phosphorus budget depends on how much of what comes in can be kept by the living part of the system from flowing out again and from being irretrievably buried. Consequently, if phosphorus balance is to be maintained, the North Sea landings have either to be of magnitude inappreciable relative to the natural exchanges, as they evidently are at present; or to be of such nature as to improve the efficiency with which losses to bottom are checked and (or) depletion of outgoing water maintained.

Leaving the question of maintenance of North Sea phosphorus balance in the above somewhat indefinite state of resolution, another aspect of the limit of potential rate of yield of phosphorus may be considered. The phosphorus income provides a measure of the equilibrium harvest, but not of the basic production of the system. A pond with an income of zero but with a considerable store of phosphorus on hand and an organization permitting rapid recirculation of nutrient to the producers could maintain a dense standing crop although without being able to come to equilibrium with any catch at all. In contrast, an appropriately constructed model with a considerable income fully utilized could nevertheless have a standing crop too sparse for profitable fishing. In the former model, any rate of continued harvest would result in a corresponding rate of deceleration of the biomass time-derivative, checked only at zero biomass or at abandonment of fishing. In the latter model, the time-derivative would at first decelerate at a decreasing rate in response to a given rate of harvest, and new equilibria could therefore be reached at levels above zero; but since even the initial biomass would (by definition) not be high enough so that the energy-equivalent of the harvest would be comparable with what could be produced by some other investment of the energy required for harvesting, fishing would not be profitable.

The North Sea is a system in which phosphorus supply evidently limits photosynthesis, and in which the natural equilibrium store of this limiting element on hand in one or another form is probably on the order of thousands of times the

maximum daily available income from outside the system. The supply of energy consumed in the living part of the North Sea system must therefore be strongly affected by the rate at which the phosphorus on hand is returned by the consumers to the producers to be recompounded with energy. The magnitude of the consuming biomass would be expected to display correspondence to rate of supply of consumable energy, and this relationship might also hold for the fraction of the biomass at high trophic levels.

What appears to be such a correspondence between standing crop of marketable fish and rate of basic production can, in a crude way, be shown by comparison of the North Sea with New England trawling grounds. For the North Sea, the average catch of marketed fish per day's absence of English steam-trawlers, 1920–1934, ranged between 1,500 and 3,000 lb. (*cf.* Baerends, 1947, fig. 3). Assuming an average of some 485 acres swept per day's absence (perhaps too high, but compare Parrish, 1949, and Margetts, 1949 *a*, *b*), the marketed catch would have run around 3–6 lb./acre (gutted weight). Even just after the first War, the level would evidently have been only some 10–12 lb./acre. Margetts and Holt (1948, pp. 29–31) give data suggesting 3–5 lb./acre in 1938, 12–17 lb./acre immediately after the resumption of fishing following War II, and 7–9 lb./acre a year later. For the catch of haddock alone, the maximum four-year average given by Baerends (1947, Table 6), 1915–18, would amount only to some 5 lb./acre. Parrish (1948, p. 7) gives gutted weights of haddock per 100 hours' fishing by selected vessels in selected areas which (assuming 27 acres swept per hour) indicate a catch of some 13 lb./acre immediately after resumption of fishing in 1945 (some four times the 1938 level).

For New England, Herrington (1948, pp. 271–2) gives data on average landings per day in 1926–31 and 1941–43 by a selected group of large Georges Bank trawlers. Assuming a sweep of 485 acres/day the results would be 30–90 lb. of marketed fish per acre, of which some 65–90 per cent was haddock. In addition, unmarketable fish (some of which might have been saved in the North Sea) amounted to 35–60 per cent of the marketable haddock taken, in years for which data are available. Herrington's sample may have been so selected or manipulated as to be above average, since, for example, whereas he gives 16,500 lb. haddock per vessel per day in 1942, Anderson and Power (1946, p. 87) give days absent and landings of gutted haddock for large trawlers in the southern part of Area XXII in 1922 corresponding only to 9,100 lb. (*i.e.*, only 19 lb./acre instead of 32 lb.). However, the indicated crops would still be far above comparable North Sea levels, unless the average fishing power of the American vessels is much greater than the European.

Merriman and Warfel (1948) give data on the catch of small Connecticut draggers fishing near the mouth of Long Island Sound in 1943–46. In this area, 90 per cent of the regularly marketed catch was blackback flounder, an exclusively American form (the remainder was mostly cod; while haddock, though sporadic in the area, was absent in the period of study). These data are also not entirely comparable with those for the North Sea and Georges Bank because they refer to round weight of sample catches of all sizes of different species per hour's fishing in different months, and are not weighted for seasonal changes in commercial fishing time. At the authors' figure of 12 acres (or less) trawled per hour, the

average poundage of regularly and occasionally marketed species in monthly sampling hauls in the different years amounted to at least 20–60 lb./acre, in addition to forms not marketed which comprised 35–50 per cent of the whole catch. The occasionally marketed species, which would probably have been saved in the North Sea, varied from less than half to equal the amount of regularly marketed ones.

It thus appears that the standing crops of marketable demersal fish per unit area in the North Sea, even after several years of rest when thought to be approaching the maximum which the region would maintain, may amount to less than those in the poorest seasons for Georges Bank and Block Island Sound after years of uninterrupted fishing of considerable intensity (according to Riley, 1949, Block Island marketed catches run about 25–50 lb. per acre per year, and Georges Bank 7–33 lb./acre/yr. This annual catch per unit area, though considerable, still seems a much smaller proportion of the standing crop than the 5–7 lb./acre/yr. obtained when yearly North Sea demersal catch, excluding war periods, is divided by total North Sea acreage). The ratio of fishable biomass on the European grounds to that on the American grounds might, at equilibrium with equal rates of fishing mortality, evidently be as little as 1 to 4 or 5.

Channel phytoplankton production in a phosphate-poor year (which is, of course, probably not representative of the whole North Sea) is estimated by Harvey (1950, p. 107) to be at least 120–200 g of dry ash-free organic matter per m^2 of area per year. From Riley's data for Georges Bank (obtained by a different method; Riley *et al.*, 1949b, p. 44), Harvey derives an estimate of 270 g/m^2/yr.; however, Riley's own estimate of annual production runs much higher, on the order of 700 g in terms of dry organic matter (*cf.* Riley, 1949, p. 18). For Long Island Sound, Riley found no maximum as high as on Georges Bank, but a much higher production average by months; however, depth of the euphotic zone was probably less; and his various estimates for total annual production in Long Island Sound (*cf.* Sverdrup *et al.*, 1946, p. 938) suggest a level under 1,000 g/m^2 (dry organic matter). Phytoplankton production in the North Sea thus seems likely to be much less than that in New England trawling areas; and it may be that the ratio under comparably representative conditions would approach 1 to 4 or 5.

Consequently, it appears possible that the standing crops of marketable demersal fish in these two shallow temperate Atlantic marine ecosystems may tend to be proportional to basic production. Basic production has been shown by Riley *et al.* (1949 *a*, b) to be a function of phosphorus supply (in the sense that, given the physical characteristics and the empirically derived physiological constants, the resultant standing crops of plant and animal plankton have been predicted with astonishing accuracy from variation in phosphate alone). Therefore, quite apart from the matter of phosphorus balance, the effects of fishing on costs of production of animal matter from the North Sea might depend on whether fishery-induced changes in composition of the biomass would significantly alter the rate of regeneration of the store of phosphorus on hand.

It is clear, from the effects of the two wars, that the North Sea demersal fishery does produce large changes in composition of that part of the biomass on which it directly bears. Even if the indicated reduction of the 1938 marketable demersal fish stock to some one-fourth of the natural level had been balanced by increase in those demersal carnivores of such size and habits as are not much caught,

significant changes in the pressures upon different parts of the stocks of prey of the marketable fish must have ensued.

Harvey (1940, p. 129) assigns to demersal fish in the Channel a daily consumption of food amounting to half of the daily production of benthos. It seems likely that the marketable demersal fish would be to a considerable extent supported by, and would be the principal consumers of, the larger and older benthos. Harvey (*ibid.*, p. 131) assumes, as a rough approximation, that about a quarter or a third by weight of the Channel invertebrate bottom fauna, comprising the young and small elements, loses by respiration 4 per cent daily on an average; the remainder burns only 1¼ per cent; and the whole community respires 2 per cent of its weight per day. If this were taken to represent the state of affairs in 1938, when the stock of marketable demersal fish was around one-fourth of that in 1945, it seems conceivable that by 1945 the composition of the stock of benthos might have been greatly changed by the increasing pressure of the larger fishes. If the change were great enough, say, to reverse the mass ratio of young and small to large and old benthos, it might evidently raise the average respiratory rate per unit weight of the whole benthonic invertebrate community nearly to 3 per cent. It is difficult to guess just what would be the corresponding effect on the total mass of benthos; but if, for present purposes, it is assumed that change in total mass would be small relative to that in composition, the benthonic respiratory requirement might evidently have increased greatly from its presumptive 1938 level of some 35–40 per cent of average daily phytoplankton production.

Phosphate concentration in the North Sea region is evidently driven below the optimum for photosynthesis during all months of favorable radiation and temperature, even in the bottom water; and there is a decline in total phosphorus in the water-column from winter to summer apparently amounting to some 25 per cent (*cf.* Harvey, 1948, pp. 357–8), which suggests the possibility of considerable seasonal accumulation in the benthos. Therefore (even if summer accumulation of dissolved organic phosphorus forms a bottleneck in recirculation), an increase in average rate of phytoplankton production of, say, one-fourth might be permitted—and entailed—by an increase in benthonic respiration of the order assumed above. In other words, the system might operate at an appreciably higher rate of phosphorus turnover under natural conditions, with a commensurate improvement in its capacity to support a crop of marketable fish. The North Sea demersal fishery might, then, significantly reduce basic production and the biomass time-derivative, even though phosphorus balance was maintained.

It seems conceivable that fishing for zooplankton-eaters might also impair the efficiency of the North Sea system (since these nektonic predators may provide a check, vital for maximal production, on the grazing of phytoplankton before the time of the spring and fall blooms; *cf.* Harvey, 1950, p. 112). Whether a direct fishery for herbivores might in part balance the reduction in rate of turnover of phosphorus brought about by a fishery for predators is not altogether clear. Neither is it obvious whether the effects of fishing would be altogether similar in shallow ecosystems of somewhat different type from the North Sea, as the broad eastern shelves of the continents in temperate latitudes; or Chesapeake Bay with a large income both of terrestrial phosphorus and of sediment; or Georges Bank where

there seems great opportunity both for exchange of water with deep sources rich in nutrient, and for loss thereto of the product of photosynthesis.

Where grazing rather than nutrient is the limiting factor for utilization of radiant energy by photosynthesis, as presumably in the Antarctic upwelling, serious reduction in the enormous abundance of quick-growing herbivores might require staggering catches. In terms of the models discussed on previous pages, the upwellings are systems with a phosphorus income high enough to support a large standing crop without regard to the amount and rate of katabolic turnover of nutrient accumulated in the area. This type of productive system might be termed *anabolic*. If efficient means to catch herbivores as small as Antarctic euphausiids are developed, the ultimate limit of yield of organic matter by the *katabolic* systems where standing crop is largely dependent on accumulated nutrient (such as the North Sea) will probably remain an academic question, even in case of greatly increased demand for food-stuffs from the sea.

Nevertheless, a grasp of the relations of income and metabolic turnover of nutrient to productivity permits the detection of misapprehensions concerning the limits of yield which might influence practical decisions (such as the mutually contradictory ones held by Baerends, 1947, and Taylor, 1951); and at the same time assists appreciation of the difficulties of deductive identification of the biologically conditioned points of inflection in the curve of diminishing returns from fishing.

2. Particular curves of population-logistics.

It has been noted in the preceding subsection that a decline in the stocks of marketable North Sea demersal fish, resulting from fishing, might cause an increase in the stocks of large and old prey. In this case, sudden cessation of fishing might permit the demersal fish reaching marketable size to draw upon an accumulated food supply larger than would exist at natural equilibrium. Consequently, it seems possible that during the two wars the marketable demersal fish might temporarily have reached levels of abundance higher than naturally sustainable under prevailing physicochemical conditions; and that the rapid postwar declines in abundance of marketable sizes might have reflected not only the resumption of trawling but temporary reduction of the appropriate food-stocks to levels less than natural. If such over-expansion of demersal fish-stocks did in fact occur, the limit for maximum equilibrium catch might evidently be placed at a lower stock-level than has been estimated from the effects of war.

The above suggestion of oscillating adjustment would seem to call for various special sorts of drastic change in relative abundances and growth rates of different size-classes and kinds of North Sea demersal fish during and after the wars, such as have apparently not been observed by workers familiar with the data (although it should be noted that there did occur in the early 1920's a temporary trough in catch per unit effort; which is attributed to the effect of poor brood years by Russell, 1942; but which might conceivably result from overrunning the food supply). Further, a countervailing buffer might exist in the form of improvement in katabolic efficiency of the system (see above). However, whether or not evidence of war-caused oscillation can be found, the indirect effects of fishing do need consideration when deductive methods or extrapolations are used.

The general problem may be illustrated by analysis of the curves of population equilibria constructed by Graham (1935) and by Baerends (1947, Fig. 1) for marketable North Sea trawl fish. These curves are such that the equilibrium contribution of a unit of weight of stock in a unit time would, when plotted against number of units in the total stock, follow a straight line (the equation for which, indicated by Baerends' Figure 1 and p. 33, is roughly $2x - 170y - 4.5$ million tons $\doteq 0$). This straight-line relationship (expressed by Graham, 1935, p. 269, as direct proportionality of rate of natural increase of the stock to the difference between mass of stock at the moment and the maximum which the area could support) means that the contribution by a unit of stock was assumed to be reduced by a constant amount for each unit added to the weight of the total stock, whether this unit increase in the total stock is the 1st or the nth. In other words, change in sustainable contribution by a unit of stock was assumed (as "a reasonable first approximation"; Graham, *ibid.*) to be inversely proportional to change in total stock.

However, it seems fairly clear that even under constant fishery-independent conditions, some at least of the factors governing contribution by a unit of stock would not be expected to change in strict inverse proportion to changes in total magnitude of the stock. For example, the change in availability of food which is represented by a unit change in equilibrium stock magnitude of the fishery stocks' prey, would presumably not be constant for a unit change in the amount of prey consumed per unit time by a changing fishery stock. Instead, it would be expected to vary with the changing situation of the prey stock in relation to its own curve of logistics. Hence, changes in energy expended to catch food per unit time by a unit of fishery stock (and in its rate of natural mortality, etc.; all of which might perhaps be subsumed under the heading of rate of utilization of food for net contribution of weight, which is not the same thing for a population as for an individual), would have to vary so as to balance the varying change in availability of food. Meanwhile, the change in the stock of prey would presumably have affected the sustainable yield of its own food, in a manner varying with the selectivity of the given fishery among competing predators and their foods, and with the habits of the food-stocks (as, predominantly herbivorous, scavenging, or predatory on these or on other predators), etc.

Regular and symmetrical behavior of so intricately balanced a resultant as that indicated may *(ceteris paribus)* occur, but it seems possible that, instead, sustainable catch of a particular stock of a complex ecosystem would often change with magnitude of the stock in an asymmetrical way. In other words, more than one critical stock level might exist for the same fishery species (for example, one peak of sustainable catch might occur after fishing has so far reduced the stock as to permit important development of a food resource previously driven far below its own level for maximum sustainable yield; a second at stock levels too low to permit epidemic transmission of a disease; and abundance might oscillate back and forth across the trough between, under the impulse of fishing). In consequence, the interpreter of fishery data might sometimes even be dealing with a curve of population growth inherently of compound type; or one so skewed that sustainable catch would tend to be inversely proportional to stock magnitude over considerable ranges of the latter, resulting in wide plateaus of maximum net product; etc.

The difficulty of reliable extrapolation from a curve of population-logistics constructed from a limited range of observations on a particular component of the biomass of a complex ecosystem, may be illustrated in still another way. We have seen that it is conceivable that basic production, and with it the capacity of the North Sea to sustain marketable fish-stocks, might be reduced as these stocks are cut down by fishing. In this case, the assumed rate of change of the slope of the upper part of the growth curve constructed by Graham and by Baerends *(ibid.)* for North Sea demersal stocks may be far too rapid (in conformity with which Margetts and Holt, 1948, indicate that stock-levels attained during the recent war may have been above the extreme limit estimated by Graham from the effects of the first war). It might even be possible that the point of maximum net product might be considerably farther above that of maximum equilibrium yield than is indicated in Baerends' curve, with consequent error in proposals for North Sea management (although in this case on the side of modesty).

Another difficulty in extrapolation caused by fishery-dependent changes is technical, although it might sometimes be of such importance as almost to be called fundamental. Curves of logistics of marine fishery stocks are usually defined in terms of relative catch per unit effort (although periodic checks of the relation of catch per unit effort to stock magnitude are generally attempted by tagging; *cf.* Sette, 1943, pp. 5, 19). Thus, in situations where catch per unit effort of a species may be affected not only by its abundance but by dependent changes in abundance of other species, construction of a reliable population curve presents special difficulties. For example, in hook and line fisheries such as that for Pacific halibut, catch per unit effort must be considerably influenced by changes in relative abundance of bait-stealers or "trash." "It is not an infrequent occurrence that the halibut men will haul in their gear and find on every hook a large rock cod, much to their disgust" (Chapman, 1942). If the halibut fishery were to favor these competing species (as it might be expected to do, since the gear and methods are designed for preferential capture of halibut, and spots where the competitors are less annoying are no doubt favored), the catch of halibut per skate of hooks would be expected to be reduced by fishing at a faster rate than is the stock of halibut, which would result in systematic distortion of a population curve based on catch per skate. Available evidence from halibut tagging seems insufficient to resolve this uncertainty.[5]

III. The Effects of Environmental Change Independent of Fishing.

1. Results of failure to discriminate fishery-independent changes:

Needler (1948) points out that even if Pacific halibut fluctuations were predominantly natural in cause, regulation of fishing might raise the levels of abun-

[5]Data on bait-loss or preoccupation of hooks therefore seem important for assured evaluation of changes in halibut catch per skate. Indications of rate of bait-loss in the past might still be obtainable, if records of bait supply have been included in fishermen's logs, and if the quantity of bait damaged in hauling, discarded when gear is taken up for the day or otherwise replaced without having been eaten, the quantity of unrecorded bait caught and used during the trip, etc., are not so great as to obscure the ratio of recorded bait-supply to catch. A less direct approach might be made by comparison of relative catches of those sizes of halibut and "trash" which are fully vulnerable to both hook and otter-trawl, when both types of gear are used in the same area during the same period. This method might simultaneously afford some indication of the minimum density of fishable halibut stock corresponding to a unit catch per skate; which would aid in resolving the contradiction between results of calculation of absolute magnitudes of halibut stock from rate of fishing mortality and catch by Burkenroad (1948), and those from catch per unit effort and catch by Thompson (1950; a method questioned by Burkenroad, 1950).

dance about which the fluctuations occur; and a similar point of view is indicated by Kesteven (1950). However, although restriction would be expected to raise the catch per unit effort at the expense of the catch, it would not be expected to improve *both* of these values unless the stock had been driven by fishing below the level for maximum equilibrium catch. But if the stock were fluctuating because of natural changes, to determine whether it was above or below the critical level would be difficult.[6]

For example, suppose that a stock were being fished at a rate considerably less than the maximum sustainable under prevailing conditions, and was in consequence declining toward an equilibrium with this rate of catch. An acceleration of this decline, by a natural change which was nevertheless insufficient to prevent ultimate attainment of equilibrium with the catch, would produce an appearance which might for a time be mistaken for overfishing. Restriction of the fishery as a result of the mistake would prevent full use of the resource, and might at the same time itself impede realization that overfishing had not occurred.

As a concrete illustration, the Area 3 stock of Pacific halibut was apparently capable during the early 1940's of achieving equilibrium with an annual catch much greater than 27 million pounds (since catch per unit effort rose from 121 pounds in 1940 to 151 pounds in 1944, at a fairly steady level of catch averaging over 27 million pounds; according to data of the International Fisheries Commission). But the annual catch was never as much as 27 million pounds from the beginning of the fishery until 1927; indeed, the average catch, 1915–1926, was only some 18 million pounds; and even in the period of highest pre-regulation catch, 1924–1930, the maximum was only 30 and the average 27 million pounds. The history of the Area 3 halibut stock is nevertheless believed to indicate rapid decline from a virginal abundance in 1912–1915 considerably greater than that in 1944, to a pre-regulation

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[6]A natural change in, say, phosphate or temperature, affecting absolute quantity of food supply available to a stock or the rate at which it can be consumed by the individual, would obviously entail change in maximum equilibrium yield of the consuming stock. A change affecting only percentage of hatch or larval survival might also, less directly, modify the maximum equilibrium catch, since if the magnitude of the brood stock required to maintain the rate of recruitment were changed, so also would be the relative food supply per fish at the stock level in equilibrium with a given rate of catch.

Fluctuations in phosphate supply (such as the notable one off Plymouth) might cause correlation between larval survival and later food supply of the year classes, not only for a particular species, but for a number of kinds simultaneously. Increase in phosphate causing improved survival of larvae would also be expected to result in an increase in the phosphorus store on hand in the system; which might not be drained away for many years after return to a lower level of income (Cooper, 1948). Hence, large year classes resulting from the fortunate concurrence of the critical larval period with a surge of planktonic food induced by improved phosphate supply, might find exceptional forage in later years as well. Thus, the fact that dominant year-classes, recognizable as such at their earliest appearance, may yet show growth and survival as good as that of much smaller broods of the same species, does not necessarily mean that the food supply is not limiting in later life.

Correlation of larval survival and exceptional later food supply might also be permitted by identity of conditions favorable to survival of both a predator and its particular prey; but unless the predator were narrowly limited in choice of food, buffering might be expected to level out the effects of fluctuations not causing change in the total biomass supported by the system. Thus, disappearance of the eel-grass does not seem to have had the drastic effect on coastal fisheries which might have been anticipated from pioneer quantitative studies on marine food-relationships. Composition of the fauna has changed since the eel-grass die-off (thus, scallops became rare in regions not providing alternative supports for the attached young), but available information does not seem to suggest the expected massive diminution in intracoastal fishable standing crops as a whole. This might result simply from utilization by phytoplankton of nutrient no longer taken by eel-grass, with resultant maintenance of the level of basic production.

minimum much less than in 1944 (average catch per unit effort over 200 pounds in 1915–16, 94 pounds in 1926 and 65 pounds at minimum in 1930). If these suppositions concerning relative stock-magnitudes are correct, and if maximum equilibrium yield of Area 3 halibut in the 1940's was considerably more than 27 million pounds, then it is hard to see why the stock should have been driven far below present magnitudes by annual catches which were so much less than 27 million pounds; unless natural conditions were formerly less favorable.

But if natural conditions in Area 3 have changed to this extent, it cannot be thought certain that the pre-regulation stock was ever driven below the level capable of yielding the maximum sustainable under the natural conditions then existent. It is true that, if the stock at the beginning of regulation had in fact been below the critical level, the legal restriction (which prevented the catch from increasing as fast as demand recovered) should have improved the rate of response of the stock to improvement of natural conditions. On the other hand, if the stock was still above its level for maximum sustainable yield when regulation of the fishery was begun, the wastage of potential catch from 1931 to date would comprise not only the increase in the stock during this period (which could be recovered), but also the cumulative unrecoverable loss resulting from the relative depression of the rate of addition which would be expected to develop as population density increased. If improvement in natural conditions has been large, this unrecoverable loss of catch would have been compensated only in part by that fraction of the rise in catch per unit effort resulting from the regulation. Loss from the restriction of the fishery might thus by now be large enough to outweigh any risks which would have been taken in 1931 if the regulations had been designed in the form of a controlled experiment able to yield conclusive evidence of the biological situation.

It can hardly be questioned that the Area 3 stock would not have increased so much as it did, without the regulations. However, whether or not the Area 3 stock was ever below the level for maximum equilibrium yield, it is difficult to believe that it was not far above any critical level in 1944. Therefore, it is not at all obvious what is the exact purpose which is intended to be served by Area 3 quota-levels; since gains from reduction of costs of production and of competition among members of the halibut fishermen's and dealers' guilds, etc., may evidently be counterbalanced by injuries to consumers, independent fishermen and dealers, ports adjacent to Area 3, etc. The lack of clarity in official thinking about the public interest which is thus mooted, gives reason for doubt of the desirability of restrictions which are not designed to be self-correcting, especially in fisheries which may be subject to significant influence from natural change in environment.[7]

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[7]The possibility has been suggested that changes in abundance of Area 3 halibut might follow a regular pattern of natural fluctuation, and that in this case, at some time not many years after 1944, "abundance might be expected to begin to drop precipitously despite whatever restriction of the fishery" (Burkenroad, 1948; a suggestion made public on January 10, 1947, before data later than those for 1944 were at hand).

The Report of the International Fisheries Commission for 1949 (1951), received after the present paper was in galley-proof, reveals that events have more or less conformed to the above prediction. Catch per skate on Area 3 declined from 151 lb. in 1944 to 110 lb. in 1949, a loss of about half the gain registered between the beginning of regulation in 1931 and the 1944 peak. This loss might amount to more than a hundred million pounds of halibut, and is thus not accounted for by the catch unless there was no recruitment or gain from excess of growth over natural mortality at all.

The Commission states *(ibid.)* that changes in the fishery during recent years have been such that actual abundance of the stock in 1949 was more than 200 per cent of that in 1930, even though

2. Difficulty of discriminating fishery-independent changes by the deductive method:

In the case of Pacific halibut fishing-area 3, it is fairly obvious that (1) the apparent magnitude of the fishable stock (as calculated on the assumption that catch per unit effort is proportional to stock magnitude and that absolute magnitude of fishable stock in a reference year is given by the quotient of the catch divided by the fishing mortality rate estimated from a tagging experiment) shows changes much greater than would be expected by subtraction of the catches from the stock (Burkenroad, 1948); (2) the characteristics of the catches do not permit absolute magnitude of stock to be estimated as a quantity small enough to allow the changes in stock-magnitude to be accounted for by the fishery, even when allowance is made for effects on rate of addition (Burkenroad, 1950); (3) the recent equilibrium yield is considerably greater than the catches which were accompanied by a decline in abundance from a virgin level presumably much greater than at present to a minimum apparently much less than at present (above).

In the case of Area 2, from which a larger harvest than in Area 3 has been taken for a longer time, the same simple approaches as the above-mentioned do not reveal an impressive discrepancy between the catch and the changes in abundance.[8] However, compatibility between a cause and its supposed effect is not the same

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catch per skate was only 170 percent. If this is true, it would seem that abundance in 1944 may have been around 275 per cent of 1930, which would perhaps be comparable with that in the early days of the fishery. Such a return to an abundance near that of 1915–16, despite a catch which had for many years been much greater than any prior to 1924, would provide additional indication that changes in magnitude of the Area 3 stock have been chiefly natural and little affected by the fishery.

If abundance at the peak prior to the decline which began in 1945 did in fact actually reach near the 1915–16 level, the possibility that there is a natural cycle regular as regards both period and amplitude seems strengthened, although the period of this cycle would apparently be under 30 years instead of "around thirty-four years" as originally suggested. It seems worth note that the marine cycle off Peru has a period of about seven years and that of New England starfish about fourteen years, so that a period of quadruple seven years for a halibut cycle might fit a widespread pattern. A renewed upturn of Area 3 abundance would on this basis be expected around 1959.

The Commission *(ibid.*, p. 23) reports that analysis of the commercial catch from one of the regions of Area 3 reveals that its age-composition in 1949 was similar to that when sampling was first undertaken in 1927, 13 and 14 year olds being predominant in a range mainly from 10 to 16 years. The Commission states that this "suggests very strongly" that such part of the recent decline in abundance on Area 3 as is "not attributable to changes in the fishery may have been a normal result of the reduced number of spawners . . . during the late 1920's and early 1930's . . ." Such a suggestion hardly seems warranted by the facts. Fish of age 13 years in 1945–49 would have been the product of the presumably rising brood-stock of 1933–37. A decline resulting from reduced brood-stock should therefore apparently have been ending, not beginning, in 1945 (and it should be noted that Thompson, 1950, p. 36, in a comparable but inverse attempt to explain an inconvenient change in the stock, states that the timing of the "secondary increase following 1936 . . . is a very strong argument in favor of the explanation that the spawning stocks were restored and are beginning to provide new young to the catch"). Actually, no close, simple, short-term correlation of brood-stock with recruitment would seem expected in a case where there is a long sea-drift of planktonic larvae to nursery-grounds, followed by a ten-year interval before recruitment to the commercial stock begins; and no such relation seems to be exhibited in the rest of the available data, from either Area.

Past parallelism of catch per skate on Areas 2 and 3, discussed in the next subsection, suggests that a sharp decline to match that on Area 3 is due on Area 2; and the Commission *(ibid.)* reports a recent reduction in recruitment which may anticipate this event. Since Area 2 recruitment is complete at the age of eight or nine years, attribution of such a forthcoming decline to the low level of the brood-stock around 1930 will hardly be considered, and a situation which should throw light on the Commission's attitudes might develop.

[8]The history of this fishery is as follows: When serious commercial fishing began on Area 2 in 1888, availability of large halibut was evidently enormous. Indeed, Thompson and Freeman (1930, p. 20) suggest that exploratory reports of scattered fish only in Area 3 at this time were merely relative ("Doubtless they were scattered in comparison to the wealth of fish found to

thing as satisfactory proof of causal relationship. The data of fishery biology are in a majority of cases so incomplete, inexact and unrepeatable that to draw definite conclusions from them demands an element of bias. It is therefore not only a legitimate but a desirable and useful procedure in this field to compare any conclusions reached with those obtainable from the operation of an opposed bias on the same data. For best results, the contradictory working hypothesis should be maintained with sufficient genuine conviction to empower a penetrating pursuit through the mazes of inference, but not so strongly as to result in the unconscious concealment of results unfavorable to the hypothesis pursued.

In the case of the Area 2 halibut fishery, the hypothesis that there has been an important change independent of fishing would lead to particular scrutiny of the reported rate of fishing mortality, which plays a strategic part in the above-described appearance of congruity between rate of catch and rate of decline of catch per unit effort. The reliability of this mortality-estimate is open to question because of the peculiar discrepancy between Area 2 and Area 3 in ratio of estimated stock magnitude to catch per unit effort (Burkenroad, 1948, pp. 97–8).

The distribution of tags among halibut in the experiments of the 1920's is described as having been deliberately related to the distribution of fishing-effort (Thompson and Herrington, 1930, pp. 28, 54). In Area 3, returns indicated that the mature fish which preponderate in the catch move freely and rapidly over the entire coast above the boundary between Areas 2 and 3; so that the tagged fish would probably tend to become more or less equally available for recapture no matter where in the Area they were tagged. In contrast, the Area 2 catch has, since early in the 1920's at least, consisted chiefly of immature fish, which are shown by

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the southward"). They state (*ibid.*, p. 27) that before 1900, and even up to 1909, a catch of 1,000 pounds per skate of the gear then used on the inshore banks (probably equivalent to more than 500 lb. per standard unit effort) "was not considered fully satisfactory fishing, causing a move to new grounds." Up until 1905, the maximum reported annual catch from Area 2 was only 28 million pounds, but in the period 1907–1913 it ranged from 50 to 60 million pounds. By 1910, even on the newly opened offshore grounds to which the fishery was extending in consequence of declining inshore abundance, catch per standard unit effort was only some 270 lb., though this still consisted chiefly of mature fish (Thompson and Freeman, 1930, p. 34; Thompson, Dunlop and Bell, 1931, p. 51). By 1915, average catch per unit effort was less than 120 pounds, and the annual catch after this date only once exceeded 33 million pounds. The winter fishery for spawning adults died out not long after 1915 (Dunlop, 1937). During the last six years of the 1920's the annual catch averaged only 26 million lb. (maximum, 27 million lb.); yet catch per unit effort continued to decline, from 56 lb. in 1924 to 35 lb. in 1930. Thereafter, at catches never below 22 million lb., catch per unit effort began to rise. It was above 90 lb. by the late 1940's, at catches above 27 million lb.

It will be seen that, if the Area 2 catch per unit effort corresponding to maximum equilibrium yield had been more than 120 lb., and the maximum equilibrium yield had been less than 35 million pounds, the history of the fishery could be explained on the basis that at some time during the decade (1906–15) when Area 2 annual catch was more than sustainable, the stock was driven below the level capable of yielding the maximum sustainable. Such an explanation would be consistent with the estimate from tagging that fishing-mortality in Area 2 around 1926 was about 40 per cent per year (Thompson and Herrington, 1931), which implies an average fishable stock in 1926 of some 65 million pounds.

Assuming for present purposes that catch per unit effort was proportional to stock-magnitude, the 1915 stock would have been more than twice that of 1926 or, say, 145 million pounds; whilst in 1905 the stock was presumably at least six times as great as in 1926 or, say, 400 million pounds. The decline in the fishable stock, 1905–15, would then have amounted to some 250 million pounds. The sum of catches during the decade was evidently around 550 million pounds; while additions to the stock might well have been no more than 300 million pounds (assuming that the stock level for maximum rate of addition was passed through during the decade, and that the maximum addition amounted to no more than 35 million pounds per annum). Thus, the estimated decline in stock agrees with the estimated excess of catch over additions.

tag-returns to remain (until grown) on the particular banks where first found. To obtain a representative rate of tag-return in Area 2, therefore, the distribution of tags would have to be made proportional to that of the population rather than of the fishing-effort.

The Area 2 fishing grounds extend along some 800 miles of coast, subdivided for statistical purposes into sectors 60 miles long. Thirteen sectors (No. 5–17) are wholly included in the Area. In both the 1925 and the 1926 tagging experiments, some 96 per cent of the Area 2 fish effectively marked were liberated within only four of these sectors (No. 10, 11, 13, 15; see *ibid.*, Fig. 2 and pp. 10, 109–111). The fishery in these four sectors where tagging was concentrated employed 60 per cent of the total effort in Area 2 and yielded 63 per cent of the total catch (in 1928–29; *ibid.*, Table 5 and pp. 52–54).

Data indicating what proportion of the fishable halibut population of Area 2 occupied the four sectors of concentrated tagging are not available. For present purposes and with appropriate reservations, it might be assumed that the area populated by halibut per linear sector, and the rate of addition to the stock per unit area populated, averaged about the same in these four sectors as in the nine where little tagging was done; and that the average density of fishable stock on the populated area in a sector was about proportional to the average catch per unit effort there.[9] On these admittedly questionable assumptions, the four sectors with 96 per cent of the tags would have contained only 34 per cent of the fishable Area 2 population. This presumptive 34 per cent of the population yielded 63 per cent of the catch. Consequently, the annual rate of fishing mortality among the tagged stocks may have been more than three times that on the rest of Area 2; and nearly double that for Area 2 as a whole.

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[9]Against these assumptions, it may be argued that those sectors of Area 2 with a more extensive area of banks or a more rapidly adding stock would (if the catch is the most important affect of catch per unit effort) be those where the fishery is concentrated. Fishing effort is presumably distributed among the sectors of an Area according to relative profitableness, which is presumably governed by the balance of numerous factors including, on the one hand, relative value of the catch per unit effort, and on the other, distance from port, hydrographic features, etc. Each sector would thus be expected to have a different relative attractiveness, even if value of catch per unit effort were equal on all. This locally characteristic non-biological attractiveness would change with development of new ports, a differently sized or powered fleet, better means of navigation, etc. But provided relative non-biological attractiveness changed less than did relative value of the sector's catch per unit effort, and provided non-biological factors were not overwhelmingly predominant in relative profitableness, those sectors on which abundance could be least rapidly reduced by a given level of sustained catch might be expected to become those of concentrated fishing effort.

However, although there is indicated to be some positive correlation between catch or effort and catch per unit effort on the sectors of Area 2 (according to data for the period 1928–29 given by Thompson and Herrington, 1930, Table 5 and pp. 52–62), this correlation is not great enough to be significant ($r_{cf} = +.31$, with a 1 in 3 expectation of a better result by chance alone; $r_{cC} = +.39$, with a 1 in 5 expectation by chance). Since the reported range of catch per unit effort on the different sectors of Area 2 was fairly considerable, from 34 pounds to 53 pounds, the poor correlation with effort suggests that other factors than catch per unit effort may have had a predominant influence on the distribution of effort among the sectors (a conclusion in agreement with the indication from the same Table 5 that, on the sectors of Area 3, there was no positive correlation at all between catch or effort and catch per unit effort, despite a range in the latter from 62 pounds to 114 pounds). Thus, there is no reason to think that the most heavily fished sectors of Area 2 in 1926 were necessarily those with the largest populations or fastest rates of addition.

A direct investigation of populated area and average population density in different sectors of Area 2, will probably be required to settle conclusively the question here raised.

Thus, if the fishing rate among the immature Area 2 stocks tagged in the 1920's was 40 per cent,[10] the overall rate on Area 2 at that time might have been only some 20 per cent. This would greatly reduce the mentioned discrepancy between ratio of estimated stock magnitude to catch per unit effort on Areas 2 and 3. Possible confirmation that overall Area 2 rate of fishing mortality in 1926 was lower than has been thought is offered by the unexpectedly sparse returns said to have resulted from the still incompletely reported tagging experiments performed on Area 2 adults in 1939–1940.[11]

If the annual fishing-mortality rate on Area 2 around 1926 was only 20 per cent or less, the decline in Area 2 population before 1930 might evidently have been too great to be accounted for by the difference between the catch removed and the additions to the stock which would have been expected had natural conditions been as favorable as recently (compare footnote 8). This discrepancy is, however, at best much less striking than the comparable one which has been demonstrated for Area 3; and so merely provides encouragement, rather than serious support, for the working hypothesis that fishery-independent changes have strongly affected abundance on Area 2 as well as Area 3.

Casting about for further promising leads, a purposively biased mind might be struck by the remarkable parallelism in changes in catch per unit effort on Areas 2 and 3, during the whole 34-year period for which records are available for both stocks (*cf.* Thompson, 1950, Fig. 1, 2). The similarity holds over a great range of change, not only for general trend but for the year-to-year steps (differences in

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[10]Ricker (1945, p. 88) points out that this 40 per cent rate is based on the instantaneous rather than the annual corrected rate of tag-return, which latter would be $1-e^{-.40}=0.33$ (although, if the average stock had not been declining, the ratio of annual catch to average stock would evidently approximate the instantaneous rate of tag return). He also notes that the particular extrapolation performed by Thompson and Herrington results in a rate theoretically somewhat too high. Ricker (1948, pp. 86–91) points out that the vulnerability of the fish tagged averaged too low; and also that tag-loss might not have been negligible as thought by Thompson and Herrington (1930), in which case upward revision of the postulated fishing mortality rate would be required (however, the evidence, *ibid.*, that strap-tags were rarely lost seems fairly satisfactory). Finally, the decline with time in return of tags from the 1926 experiment seems to have been less than that in the 1925 experiments from which the 40 per cent rate was calculated (Thompson and Herrington, 1930, Table 9); though fishing-effort was increasing. Taken altogether, it is difficult to judge just what the ratio of annual catch to average stock-magnitude during the year may have been among the Area 2 fishable stocks on which the tagging experiments were performed, but somewhere between 30 per cent and 50 per cent seems likely.

[11]These mature fish were recovered from all parts of Area 2, in a fashion like that on Area 3 in the 1920's (Int. Fish. Comm., 1949). The low rate of return has been interpreted *(ibid.)* as meaning that "the rate of return from tagging on spawning congregations is not representative of the population as a whole," and, as pointed out to me by Dr. W. E. Ricker *(in litt.)*, the fishing season in Area 2 had indeed become so limited that in 1940 the adults may not have returned from the spawning grounds in time to become fully vulnerable to fishing.

However, although such reduced vulnerability would invalidate the present interpretation of the 1940 experiments, it is a special feature of the recent situation which does not seem to bear upon interpretation of the results of the tagging experiments in the 1920's. Objection to the present view that rate of tag-return from adults on Area 3 was representative might of course be made on other grounds; for example, adults dispersing from spawning grounds may home to their banks of origin. Heavily fished juvenile stocks might be expected to contribute relatively fewer adults to the spawning populations. Hence, if the spawners afterwards home, and if they spend much of their time on the home banks rather than in transit to and from the spawning grounds, tagging on the Area 3 spawning grounds in the 1920's might have yielded disproportionately low returns. However, since evidence of homing would presumably be conspicuous among records of halibut tagged while young and recovered after maturity, the lack of report that homing occurs suggests that it does not.

Since the foregoing was set in print, Report 15 of the International Fisheries Commission, for 1949 (1951) has been received. On p. 16, it states that "Much biological evidence was and is at hand to demonstrate the relative lack of interchange of stocks between subsections of Area 2

direction of which result from only five occasions of out-of-line change); and it is as about as marked during the 16 years before regulation began in 1931, as in the 18 years afterward.

Coefficient of correlation of catch per unit effort on the two Areas is (by rank difference, r_s) +.88 for both the pre- and the post-regulation years. The closeness of the relationship is strikingly brought out by plotting catch per unit effort in one Area against that in the other, for each year (Figure I). It will be seen, from the remarkably compact distribution of the points around the regression line drawn in Figure I,

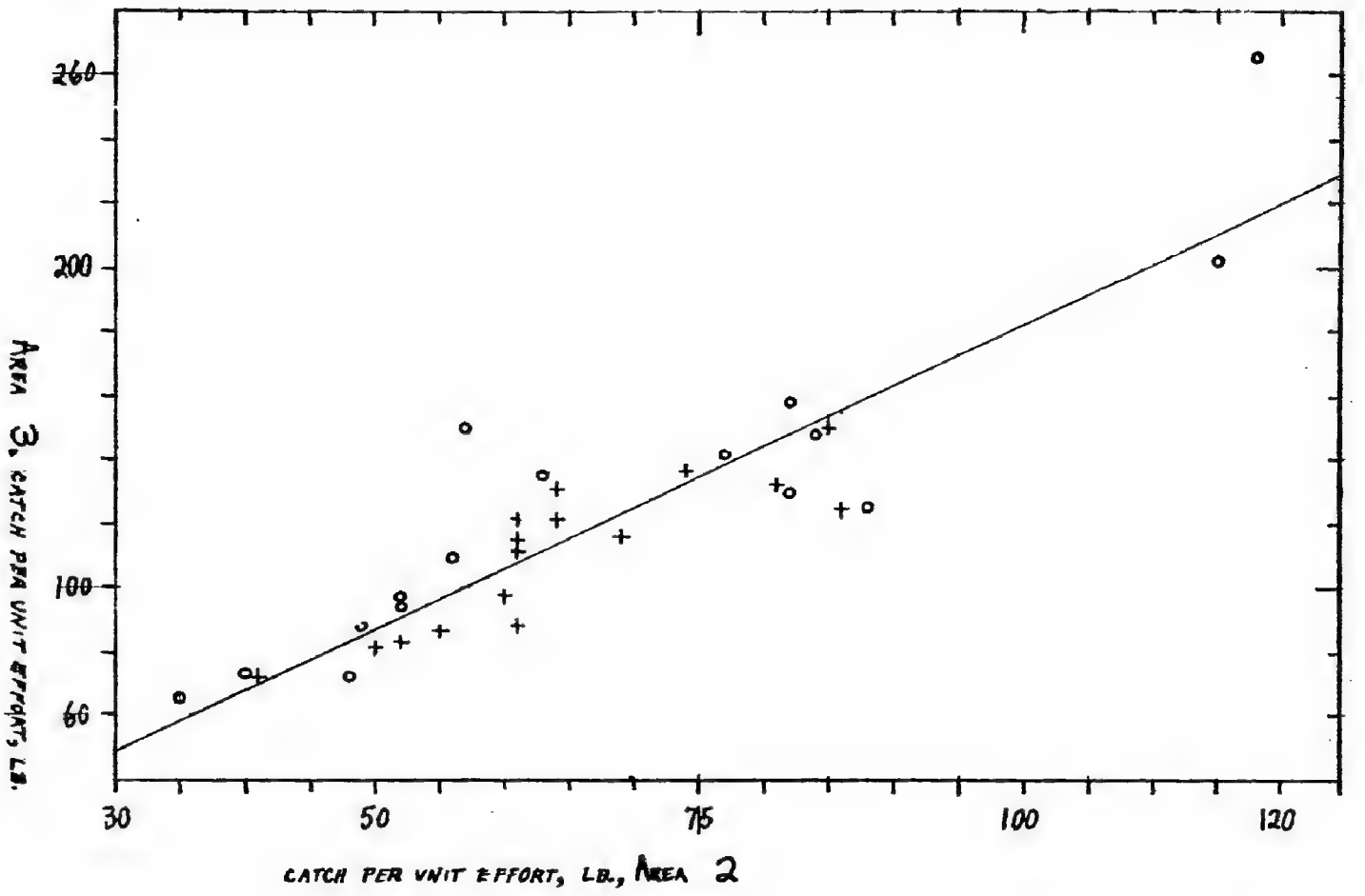

FIGURE I

Relation of each year's average catch per unit effort in Area 3 of the Pacific halibut fishery to that in Area 2, during the period 1915–1946. Data from Thompson (1950) and International Fisheries Commission (1948). Regression $Y=1.85\ X\ -1.5$; $s_{y,x}=19$ lb. Years prior to regulation of the fishery (1915–1930) denoted by o; years after regulation began (1931–1946) denoted by +.

that relative apparent abundance in one Area can be predicted quite closely (perhaps even within the limits of variation in ratio of catch per unit effort to actual abundance) from that in the same year in the other Area. Expressed in another way, although the ratio of annual average catch per unit effort on Area 3 to that on Area 2 has a fairly considerable range of variation (34-year mean, 1.8 ± 0.3), this ratio shows no very significant trend (Table I, Figure II). During the years before regulation, 1915–1930, the ratios ranged from 1.4 to 2.6, mean 1.9; during the

. . . Tagging experiments on spawning grounds in Area 2 showed that the mature fish migrated within relatively restricted sections of the area adjacent to the place of marking. . . ."

It is impossible to interpret this flat contradiction of Report 14 for 1948, which states (p. 21) that "The Cape St. James experiment in the winter of 1939–1940 corroborated the belief that Cape St. James was a spawning congregation point for the Area 2 stock as a whole. . . . As in the case of the Cape St. James experiment, recoveries [from similar winter tagging on grounds between Hippa Island and Cape Spencer] were made throughout Area 2." This inexplicable conflict, concerning a matter which is not only of theoretical interest but which affects a proposal for change of the regulations, seems to point up the Commission's neglect of its obligation to submit details of its evidence for public inspection.

18 years after regulation, from 1.3 to 2.1, mean 1.7. For 1915–1922, the mean is 1.8; 1923–1930, 1.9; 1931–1939, 1.7; 1939–1948, 1.7.

Such a relationship suggests as a possibility that catch per unit effort is governed by the same factor on both Areas. Against this, it must be granted that even if abundance on Area 3 had been heavily influenced by factors independent of fishing (as indicated by preceding analyses), Area 2 might simply have been kept fished down to the same level of profitableness as Area 3. But if this had been the case, the ratio of the fishing-efforts required to maintain the parallelism of catch per unit effort on the two grounds would have depended on whether or not the two stocks were equally over- or under-fished. If the Area 3 stock were above the level required for maximum equilibrium yield, the catch required to prevent a unit increase in Area 3 stock-magnitude would be expected to become less the greater the stock. If the Area 2 stock were below the level for maximum equilibrium yield, then the greater this stock became the greater the catch which would have been required to prevent further increase in stock magnitude. Thus, since the changes in catch per unit effort were parallel, the ratios of catch or effort on the two Areas might provide a clue to the situations of the stocks in relation to their respective inflection points.

The catch and the effort on Area 3 tended through 1922 to decline somewhat, relative to those on Area 2 (Table I; Figure II). In 1923–1925, however, these ratios showed a steep rise after which a relatively high, quite constant level has been maintained. The correlation between these parallel ratios of catch and effort

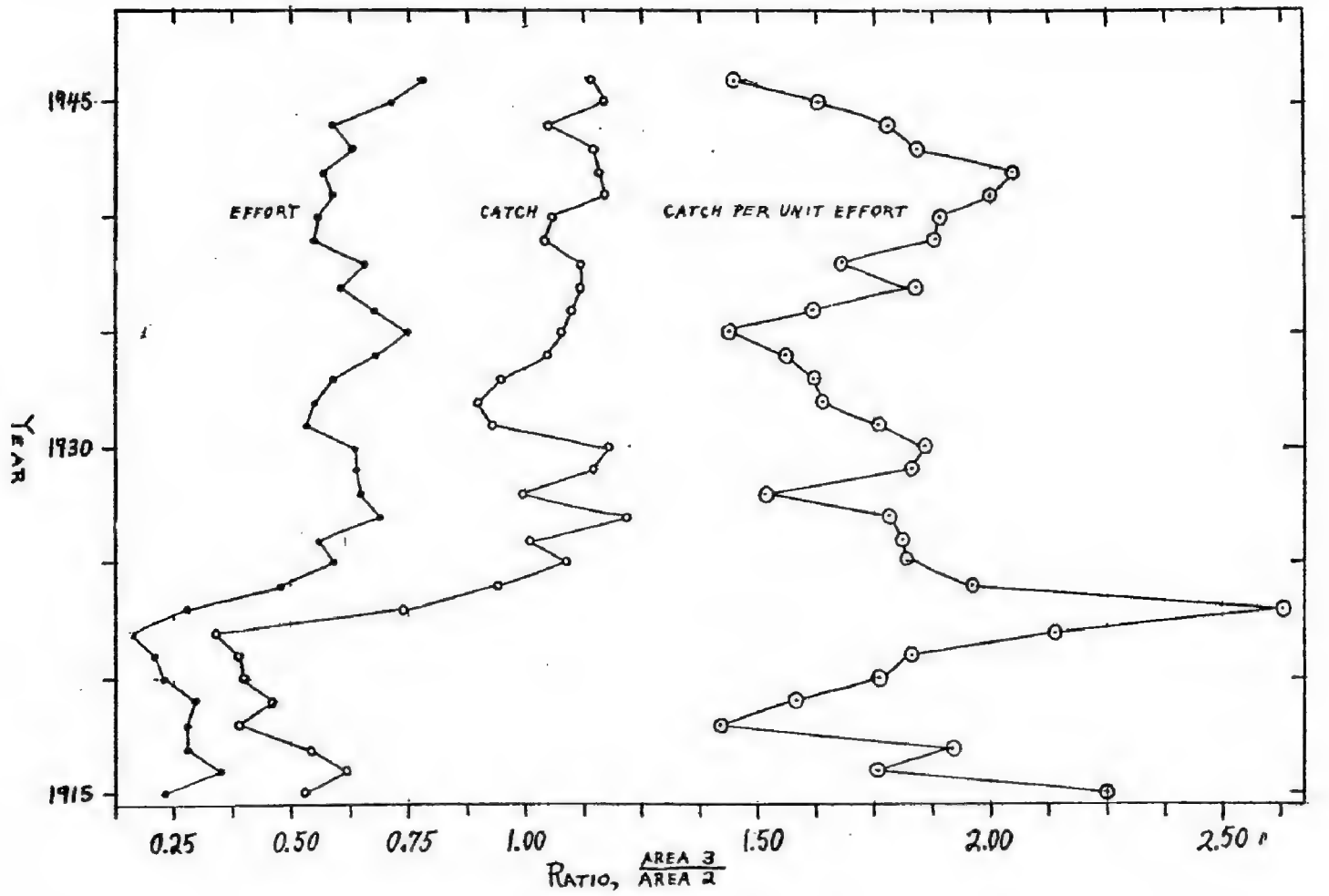

FIGURE II

Ratios of effort, catch and catch per unit effort on Pacific halibut Area 3 to those on Area 2 in the same year, by years during the period 1915–1946 (see Table I). Ratios of effort denoted by a dot; of catch by a circle; of catch per unit effort by an encircled dot.

on the two Areas is high ($r_s = +.82$), but neither ratio alone shows any clear simple relationship to the ratio of catch per unit effort on the two Areas.[12]

TABLE I

Ratios between catch, effort and catch per unit effort on Pacific halibut Area 3 and those on Area 2 (from data presented by Thompson, 1950, and International Fisheries Commission, 1948, 1949).

Year	Ratio, Area 3/Area 2 Catch	Effort	Catch/effort	Year	Ratio, Area 3/Area 2 Catch	Effort	Catch/effort
1915	0.53	0.23	2.25	1932	0.90	0.55	1.64
6	0.62	0.35	1.76	3	0.95	0.59	1.62
7	0.54	0.28	1.92	4	1.05	0.68	1.56
8	0.39	0.28	1.42	35	1.08	0.75	1.44
9	0.46	0.29	1.58	6	1.10	0.68	1.62
20	0.40	0.23	1.76	7	1.12	0.61	1.84
1	0.39	0.21	1.83	8	1.12	0.66	1.68
2	0.34	0.16	2.14	9	1.04	0.55	1.88
3	0.74	0.28	2.63	40	1.06	0.56	1.89
4	0.94	0.48	1.96	1	1.17	0.59	2.00
25	1.09	0.59	1.82	2	1.16	0.57	2.05
6	1.01	0.56	1.81	3	1.15	0.63	1.84
7	1.22	0.69	1.78	4	1.05	0.59	1.78
8	0.99	0.65	1.52	45	1.17	0.72	1.63
9	1.15	0.64	1.83	6[13]	1.14	0.82	1.40
30	1.18	0.64	1.86	7[13]	1.02	0.71	1.42
1	0.93	0.53	1.76	8[13]	1.01	0.77	1.31

This presumably means that the short-term fluctuations in ratio of catch per unit effort were of no significance for the present line of reasoning. Therefore, on

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[12]There is some slight correlation between the catch or effort ratio and the ratio of catch per unit effort four years earlier; and r_s for the effort ratio may be brought up to +.47 (with rejection of the null hypothesis around the 1 per cent level) if the effort ratios of the early period are raised in relation to those after 1927 by adding the quantity 0.35 to each. Such weighting of the early ratios might be justified on the ground that the sharp change in effort ratio from the level of 1915–1922 to that of 1928–1948 suggests an economic change which greatly increased the relative attractiveness of Area 3 (presumably the rapid changeover to diesel power after 1922; see Thompson and Freeman, 1930, pp. 46–7).

However, the interpretation of such a delayed relationship would not be clear even if it were real. Four years seems rather long for lag in fishermen's reaction to changes in relative attractiveness resulting from changes in catch per unit effort.

[13]There is considerable confusion in the statistics of the halibut fishery, some of which seems unnecessary or even deliberately fostered. The values for 1946–48 used in obtaining the ratios given in Table I above are especially uncertain.

Without going into details of minor conflict, it seems desirable to state that the following caches per skate have been arbitrarily chosen here among the alternatives which Thompson (1950) and the Commission's Reports for 1947 and 1948 permit: Area 2, 1946, 86 lb.; 1947, 86 lb.; 1948, 93 lb.; Area 3, 1946, 120 lb.; 1947, 122 lb.; 1948, 122 lb.

Concerning the values for Area 3 in 1947 and 1948, some further remarks seem justified. The Report for 1947 gives "size of the stock" for Area 3 as 89 per cent greater than in 1930, which would evidently represent $1.89 \times 64.7 = 122$ lb. per standard skate. The Report for 1948 says that Area 3 abundance "was the same as in 1947"; but adds that "More detailed studies . . . indicate that the catch per unit effort in Area 3 has increased 137 per cent from 1930 to 1948". This would naturally be taken to mean that the Report for 1947 had been found in error and that the catch per skate in 1947 and 1948 was actually $2.37 \times 64.7 = 153$ lb., slightly more than the 1944 level. This value was consequently used in preceding drafts of the present paper, and it was not until the Commission's Report for 1949 (1951) was received, after the present paper was in galley-proof, that the true state of affairs was grasped. The Report for 1949 (p. 21) remarks that on Area 3 subsequent to 1944 "a gradual recession occurred. . . . By 1944 . . catch per skate had declined to about 110 pounds. . . ." The Report goes on to say in a footnote that "on account of the marked changes in the fishery and the complex character of the stocks" the Area 3 index of comparison with 1930 requires modifications which would lift the value for 1949 from an uncorrected 70 per cent to "more than 100 per cent above the 1930 level." It thus appears that the "139 per cent"

the hypothesis that fishing was the principal affect of catch per unit effort on at least one of the Areas, the lack of strong trend in the ratios both of catch per unit effort and of catch or effort in the period 1925–1948 seems to imply that the stocks on the two Areas were in a comparable situation as regards their respective levels for maximum equilibrium yield. This argument is not a conclusive one (since, for example, the slopes of the population-growth curves of the two stocks might have chanced to differ in just the manner required to offset the difference in relation of the stocks to their levels for maximum equilibrium, during the period of observation). It does however afford a simple explanation of the peculiar fact that not only the changes in catcb but the effects of these changes on the rate of natural increase of the stocks have been similar (or insignificant) on both Areas.

If it is assumed, in accordance with the foregoing, that the stocks of Areas 2 and 3 must (unless governed primarily by a common natural factor) have maintained a comparable relationship to their respective levels for maximum equilibrium yield, the question still remains open whether they were both simultaneously above or both simultaneously below this level at any given time. The statistics of the Area 3 fishery indicate that natural changes affected abundance so much more than did fishing as to leave no secure basis for belief that this stock has ever been overfished. Therefore, it seems possible that the Area 2 stock may not have been driven below the level capable of maximum sustainable yield either. This is not to assert that Area 2 could have sustained a catch of 50–60 million pounds per year even under the most favorable conditions, but merely to question whether the period of high catch was sufficiently long-sustained to reduce the stock below its level for maximum equilibrium yield.[14]

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given in the Report for 1948 must have referred to the same 122 lb. per skate as did the "89 per cent" in the Report for 1947. In other words, the higher and more favorable-sounding value given for 1948 was obtained by a change in method of calculation introduced without explicit notice; and means to compare it with other years than 1930 are still lacking two years later.

Since nothing is said in the Report for 1949 concerning the presumably similar need for correction of the raw catch per skate on Area 2 (where there has apparently been no marked decline as yet, since the 1949 catch per skate is given as "over 90 pounds"), it is difficult to believe that the Commission has been concerned to clarify the Area 3 situation. Details of the method of correction which has been adopted will be of interest, since such operations are notoriously difficult.

The Report for 1949 (p. 19) also introduces an "abbreviated" table of catches in Areas 2 and 3, which "differ from the reported catches, published elsewhere, as they include corrections for poundage reported from the wrong area and for commercial poundage estimated to have been landed but not reported." This Table selects so few years as not to be usable for present purposes; and since those corrections which are given are not large enough to make a significant difference in present results, they have been ignored. However, it seems worthwhile to emphasize here that when serial data are corrected or amended, it is customary to make every effort to facilitate full comparison with values previously offered.

[14]Thompson and Herrington (1930, p. 71) have calculated from the results of the tagging experiments on Area 2 in the 1920's that the rate of natural mortality for the preponderantly immature and relatively heavily fished stocks tagged was considerably greater than the reported rate of individual growth given by Thompson and Bell (1934). This estimate of natural mortality rate can be questioned, and so (I am informed by Dr. Ricker) may be the estimated rate of growth; but if anything approaching this situation existed, it would be unexpected in an overfished stock of a species such as halibut. This would encourage the view that additions to the Area 2 stock during the 1920's might, if natural conditions had not been worsening at a rate sufficient to outweigh the favoring effects of declining population density, have risen to a level more than sufficient to balance the demand permitted by the rising costs of production.

It is of interest, in the same connection, to remember the opinion of Thompson and Freeman (1930, p. 20) that virgin abundance on Area 2 was far greater than that on Area 3. The ratio of magnitudes of different stocks of a given species at their natural equilibrium levels might be expected *(ceteris paribus)* to be similar to the ratio of the maximum equilibrium yields of these different stocks. Therefore, if the Area 3 stock was able to increase by an amount probably around a hundred million pounds between 1940 and 1944, despite a yield of more than 27 million lb. per year, it might be suspected that the decline of Area 2 abundance was considerably more rapid than

The results of scrutiny of the Area 2 data from a viewpoint opposed in bias to that taken by the International Fisheries Commission thus justify the procedure, since they provide some reason to think that fishery-independent changes in Area 2 stock-magnitude might have been of importance. On the other hand, application of this procedure to the North Sea demersal fishery has not resulted in discoveries such as might require much modification of prevailing beliefs.

Unlike the regulation of the Pacific halibut fishery, for which there is no control situation, the two great wars have provided what is, in effect, a controlled experiment in restriction of North Sea trawling. The results of this repetition (which was independent of abundance and price) of a sudden large cut and a subsequent restoration of fishing effort prove that catch here has an immense influence on subsequent catch per unit effort, and one sufficient to drive the stocks below their critical levels. Suppose that the pre-1915 demersal stocks had been at or above the level for maximum equilibrium yield; and that therefore, as population grew denser in consequence of war-restricted fishing, they would *(ceteris paribus)* have been unable to add to themselves yearly as much as the amount of the prewar catch. In this case, so great an absolute increase in the marketable stocks as is suggested on the basis of rate of prewar tag returns by the rise in catch per unit effort found in 1919 would not have been expected from the war-caused reduction in catch. But the increase during the second war, quadrupling the 1938 availability, was again to or beyond the 1919 level (and is thought to have resulted from improvement in survival rather than in growth-rate or broods; *cf.* Baerends, 1947; Graham, 1948); and resumption of fishing has again been followed by a sharp decline in abundance. Thus, an explanation of North Sea data seemingly indicative of overfishing in terms of fishery-independent natural change would require a highly improbable number of coincidences.

Improbable occurrences are by no means to be treated as if impossible, and there are some few features of the North Sea record which might favor suspicion that fishery-independent changes may have been more important than is usually granted.[15]

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the fishery would call for (unless the virgin ratio of stock-density to stock-magnitude on Area 2 was much greater than that on Area 3; which is not suggested by available data on relative extent of populated grounds in the two Areas).

[15]For example, there seem to have been rather high correlations between catch per unit effort in the New England trawl-fishery for adult haddock, and that in various parts of the North Sea demersal fishery, at least in certain periods (compare Herrington, 1948, with Thompson, 1930, and Baerends, 1947). In particular, for North Sea sail-trawlers, 1919–1935, correlation with Georges Bank is $r_s = +.81$. The meaning of these parallelisms has not been very carefully considered; but they do suggest the possibility of influence on the North Sea stocks by a factor common to the whole North Atlantic.

Whether this presumed common factor is economic or natural, and if natural how important relative to fishing, is not clear. Simultaneous occurrence of dominant year classes on both sides of the Atlantic is known, but apparently not for haddock. Haddock abundance may, however, be subject to massive long-term natural change in New England waters (Burkenroad, 1948, pp. 114–5), and it is conceivable that a parallel trend might affect North Sea trawl catches.

World-wide change in general economic conditions might cause parallel changes in North Sea and New England abundances through changes in fishing intensity; but the relationship of abundance of New England haddock to fishing is by no means clear (*cf.* Herrington, 1948, especially the discussion, pp. 279–81; and also Schuck, 1949. It will be observed that Schuck is mistaken in thinking that the high correlation between catch and decline in year-class abundance means that changes in the catch account for 66 per cent of the changes in decline. Instead comparison of catch and decline with initial abundance indicates that change in the latter probably to a considerable extent controls both the former. Likewise, Schuck's observation, that when the regression line of catch against decline is extrapolated it passes through the origin, does not mean that natural mortality is nil, but merely that if there were no haddock to start with, both catch and decline would be zero). A common economic factor might influence efficiency of the fishing

However, these features are not very imposing ones, and apart from them, it seems necessary to believe that, either the 1914 and 1938 North Sea demersal stocks were below the level for maximum equilibrium catch and began to add themselves at a more rapid rate as population density and average age increased during the wars, or the stock-levels of 1919 and 1945 were greater than could be sustained under existent natural conditions, even if there had been no increase in fishing.

There is some theoretical basis for entertaining consideration of the latter possibility, since a sudden great change in fishing mortality rate might result in an oscillating adjustment of the relations of predator to prey (see p. 193 above). However, even with benefit of bias against claims of North Sea overfishing, it is difficult to doubt that the present North Sea demersal fishery has so great an effect on abundance that it would be economically feasible to fish the stocks below the critical level in the near future, even if this has not already been done in the past. Thus, the practical question to which the possibility of North Sea fishery-dependent oscillation relates is the exceedingly intricate one of when or whether which components of the demersal fishery stock have already been reduced below their levels for maximum equilibrium yield. This question is not of the same gravity as the one about Pacific halibut raised in the present section (which latter is, essentially, whether fishery-independent changes have been so great as to make relatively insignificant the effects of the fishery); and it need not here be pursued.

The foregoing indicates that predictions concerning effects of change in exploitation on abundance of North Sea demersal stocks have some degree of reliability, whereas those for Pacific halibut are questionable. This difference does not seem to arise entirely from differences in the duration, extent and quality of the research devoted to these fisheries. Instead, it seems to result from the fact that regulation of the halibut fishery is an uncontrolled experiment, so that reasoning about its results is necessarily deductive. In contrast, the twice-repeated restriction and subsequent resumption of North Sea fishing caused by the wars permits use of inductive reasoning. Except for the wars, it would be difficult to be sure that the North Sea had been overfished.[16]

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effort rather than abundance; but corrections for introduction of Vigneron-Dahl rig, radio, fathometer, etc., have evidently been made in the New England index (Herrington, 1948, pp. 250–254), and would presumably not be necessary for North Sea sail-trawlers.

General economic conditions may of course also influence efficiency of fishing effort in ways for which correction is difficult. A fall in ratio of prices to charges on capital might affect both the *real* efficiency of the effort (which can be regarded as a function of the proportion of the fishable stock which is removed from a unit area by a unit effort) and the *apparent* efficiency (which could be treated as a function of the ratio between the average quantity of fish on the unit areas actually fished and the average quantity per unit area over the whole range of the stock), by forcing the accomplishment of more (and therefore less selective) fishing upon the survivors of the pinch. Considerable effects of general economic conditions on efficiency of effort have been recognized in some fisheries (*e.g.*, Alaska razor clam; Thompson and Weymouth, 1935). However, there is no close correlation between catch per unit effort in the New England haddock fishery and some others in which efficiency of effort might be expected to have been similarly affected by economic changes (as for example, Pacific halibut, which although it too displayed its lowest catch per unit effort at the beginning of the great depression, otherwise has a quite different record). Therefore, it seems possible that such affects were relatively unimportant.

[16]This statement rests upon the results of analysis of Graham's attempt to demonstrate overfishing of North Sea cod through calculations from growth and age-census data (1935, pp. 206–269). It is the validity of the reasoning, not of the conclusion, which is here examined.

Graham deduces that if the fishing rate for North Sea cod were sufficiently reduced to raise average age of the fish caught from 2.5 years to 3.5 years, the yield then sustainable would at least equal that obtained at the higher expenditure of fishing effort. The argument is based on calculations from the observed relative numbers of fish of different ages in the heavily fished

In other words, use of inductive methods seems as yet to be required for assurance of biologically effectual exploitation.

IV. The Inductive Method in Marine Fishery Biology.

The penetrating study by Sette (1943) of requirements for deductive approach to the problem of biologically effectual exploitation of California pilchard, and the relatively enormous expenditures which have been made for this investigation, suggest that the costs of adequate research along these lines will not soon be forthcoming for a majority of fisheries. At the same time, it remains to be seen whether the pilchard investigation will in fact succeed in identifying the inflection points, by whatever elaboration of deductive methods (*cf.*, Tester, 1949, on the necessity of experimental investigation of the effects of fishing on British Columbia

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stock: the observed average weights and average rates of individual growth of these fish at different ages; and "some probable values" for natural mortality at different ages. Graham assumes in his table of calculations that natural mortality and growth at the different ages, and the number of young annually reaching fishable size, would all remain the same even if the density of the stock were increased.

On this basis, the "rate of natural increase" would change only as did the age-composition of the stock. Graham's calculations show that, for a moderate change in average age of the stock, reduced mortality would thus more than compensate for slower growth. In order to reduce the new equilibrium yield below that in the previous younger population, "either the change in natural mortality rate or the new natural mortality rate has to be quite ridiculous, from the information we now have . . . we are only proposing to raise the average age from 2½ to 3½, in a fish which is first mature at about 5 years of age, and it is really very unlikely that in these young fish the [average] natural mortality rate [for the whole fishable stock] would thereby be raised. In fact, we would expect it to fall. Yet if we make the change only zero, we find that the new mortality rate has to be as high as 41 per cent" (which is double the rate assumed even for the youngest fishable age-group in the heavily fished stock).

However, the curves of rate of natural mortality and of growth against age would in reality be expected to be transposed bodily to new levels with increase of stock density (in consequence of increase in rates of cannibalism, disease, competition for food, etc.), and these changes might also be expected to reduce the percentage of starting young which live to reach fishable size. The question is, whether the curve of these various rate-changes against stock-density would rise steeply enough to offset the net gains from increasing age calculated by Graham. In the particular case, the observed effects of the wars do indeed make it likely enough that the net result of so modest an increase in density in a stock so young would be advantageous. But, as far as Graham's cited data go, there is nothing to oppose other assumptions. Suppose recruitment and weight, growth, and mortality of the different age-classes at Time 2 in Graham's Table were slightly modified from those at Time 1, enough to reduce G_2 from 0.65 to, say, 0.60. Then the M_1 and M_2 required if Y_2 is to drop below Y_1 become concordant enough with the new assumption that average natural mortality of the fishable stock would be somewhat increased at the new balance of average age and stock-density.

In fact, Graham's assumptions are such as would make almost any heavily fished stock appear to be below the level for maximum equilibrium yield. In this sense, he has assumed the point at issue, and his argument is circular. What he has really done is not to prove overfishing by age and growth-census data, but to construct one among a variety of models permitted by the data.

Now suppose that, as a result of Graham's argument, regulation of trawling had been undertaken; with results more or less corresponding to those which he assumed would ensue. Such demonstration of insignificant change in other parameters than fishing mortality would have afforded a strong presumption that the demersal stocks really had been overfished. But still, the question would remain whether there might perchance have been a coincident natural change in, say, temperature, currents or phosphate (which, it should be noted, might cause parallel changes in a number of species-masses), to which a critical part of the improvement in "rate of natural increase" should have been credited.

To exclude the possibility of coincident fishery-independent change, it would thus have been necessary, say, to relax the regulations, then tighten them again, to see if the same results would be repeated. It is such conclusive evidence against independent changes which has been provided for the North Sea by the wars, and which in the present state of development of marine science can hardly be obtained by deduction, even with better data than Graham's, from observations on recruitment, growth and death (or catch and catch per unit effort either) in a narrow or uncontrolled range of circumstances (*cf.* Sette, 1943, p. 26).

herring; also the remarks of Needler, 1948, pp. 170–1). As has been indicated on preceding pages by analysis of demersal fishery situations, the fact that a stock is pelagic and is subject to relatively great natural mortality and variation in availability merely enhances the basic difficulties of deductive approach, which seem to exist for almost all marine fishery problems.

Nevertheless, with or without an adequate basis, marine fisheries are going to be regulated. In many cases, a good part of what is phrased as "conservation in the public interest" really concerns immediate advantages to limited special groups; in many other cases it is simply not realized that knowledge of the effects of the fishery is inadequate; in still others, the immediate risks from failure to regulate are considered graver than the possible long-term loss from misguided regulation. In all these cases, there are risks of indefinitely continued injury to society, because the form of the restrictions is not such as to provide assured evidence of their effectuality and they may therefore be maintained indefinitely even though actually disadvantageous.

Among politically active interests concerned with fishing, there is usually opposition as well as favor toward restrictions, such that a compromise concerning changes in the *status quo ante* would often be politically feasible. Such a compromise could permit design of regulations in a form equivalent to controlled experiment.[17] Although the proposal by Tester in 1946 (unpublished) for an adequately controlled sea-fishery experiment (by means of an alternation between two years without restriction in the British Columbia herring fishery and one of complete closure, over a period of at least 12 years) was rejected in favor of a program which cannot be expected to yield as conclusive results (partial removal of restrictions on one local population while they are rigidly maintained for another), this pioneering proposal appears to have been a feasible one, economically and otherwise. It may be expected that as the principles involved become more familiar, good experimental design will be sought rather than resisted.

To the extent that the more significant effects of exploitation are definitely known, the indirect costs to society of the use of fishery regulations for large-scale controlled experiment could not be justified. However, it is the present suggestion that (except where use of inductive reasoning has been made possible by accidents) available proofs of past or prospective benefits of regulation of marine fisheries

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[17]For example, sportsmen, commercial fish-catchers, and many deep-water shrimp trawlers urge the closure of Texas bays to market-shrimping. Other trawlers, especially those with smaller boats, object. Knowledge of the effects of population-density of young shrimp on their rates of growth and mortality is insufficient for assurance concerning the effects of nursery-ground trawling on subsequent abundance of adults. Although shrimp are (when available) an important item in the food of prized bay fish, and although the young of these fish are occasionally caught in bay trawling, it is uncertain just what would be the sum effect on fish of closure of the bays to trawling (at any rate, those who think closure will improve shrimp catches must to some extent contradict the opinion that it will improve fish catches). Mere closure of the bays (as has been done for some years past in South Carolina) will evidently not in itself yield decisive evidence of its effects. For example, recent high salinities in the Aransas area caused by a drought of several years' duration, are probably involved in the sharp decline in abundance of young white shrimp; and closure of the bays to trawling will presumably at some point be followed by the end of the drought, with inextricable confusion of causes and effects.

If opposition to Texas closure is sufficiently balanced against approbation, it should be possible to obtain support for a trial-and-error compromise consisting of regularly alternating years of opening and closure; which, if the results are properly observed, should in time provide statistically admissible evidence on which to base final action.

often have an unfortunate degree of resemblance to the Butcher's proof of identification of the Jubjub (Dodgson, 1876). If this be true, it should be a leading principle with marine fishery biologists to explain and emphasize the need for use of sound inductive methods to test the effects of fishery regulations.

The limitations of the experimental situation seem to require that controls be provided by alternation of periods of relative freedom with those of restriction, to an extent and frequency (and on a schedule) permitting calculation of the probability that observed gains or losses correlated with restriction were caused by something else.

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It may not be necessary to emphasize that the concepts and data here used (and perhaps, though unintentionally, misused) have all had a long history of elaboration at the hands of a host of able men, and that the limited number of references cited has no relation to the extent of the sources to be acknowledged.

SUMMARY

1. *a.* The major present function of marine fishery biology is, to predict the effects of exploitation upon fishery stocks, in order to supply premises for the social and economic predictions upon which are based the value judgments represented by management policy.

b. The tangible net gains to society which are at present obtainable from prescriptive restriction of sea-fishing would apparently at best be relatively small; but the accompanying improvement in knowledge of interactions between man and environment may have great importance.

2. *a.* The limits of potential marine harvest are in some regions probably strongly influenced by the rate of metabolic turnover of the store of limiting nutrient on hand in the system. In such *katabolic* ecosystems (as the North Sea) it is probable that fishing may reduce not only the standing crops of marketable fish, but also the ability of the system to support them, as a result of its indirect effect on respiratory rate of the biomass.

b. A second type of indirect fishery-dependent effect which may yet prove to be of importance is, oscillatory adjustment of predator-prey relationships to

sudden changes in fishing-intensity. It is suggested that the accuracy of extrapolations from population-curves for North Sea demersal stock which have been based on observations of war-caused changes, may have been significantly affected by such oscillation.

3. *a.* It is impossible to question seriously the conclusion that North Sea demersal stocks have been or can easily be driven by commercial fishing below the levels for one or both biological inflection points in the curve of diminishing returns from increased fishing. In contrast, however, serious doubt of current beliefs concerning effects of exploitation on Pacific halibut is legitimate, since data for the latter do not exclude the possibility of major effects from fishery-independent changes in the environment.

b. It therefore seems possible that effort saved through management of the Pacific halibut fishery has been more than matched by countervailing sacrifice of catch. The difference in reliability of predictions concerning North Sea demersal and Pacific halibut fishery stocks appears to rest upon use of inductive methods in study of the former fishery, an approach there permitted by the accidents of war.

4. *a.* It is concluded that the degree of accuracy of biological predictions attainable by use of the usual purely deductive methods is unlikely to be sufficient to permit reliable socioeconomic predictions.

b. Regulations which are to be applied to marine fisheries should therefore as a matter of principle be designed in form equivalent to controlled experiment, by provision for arbitrarily scheduled periodic relaxations of restriction sufficient in extent and number to permit statistical analysis of the results.

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